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MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

REPORT

FOR THE YEARS

1946–1948

Issued by the
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ASSOCIATION LIMITED
YAXLEY · PETERBOROUGH
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Contents

	Page
Preface by the Chairman	4
Staff	6
Introduction	7
Programme	8
Cropping Experiments	11
Chemistry Department	44
Microbiology Department	64
List of Publications	71

Illustrations

The main laboratory	5
Experimental composting shed	10
Test house	10
Method of wetting bales of straw	19

PREFACE

Early in 1945 I went to Selby to see Stanley Middlebrook and we two discussed, amongst many other things, the need for some scientific knowledge of mushroom growing. On my return from Selby I saw Mr. H. F. Atkins and his son, Fred. C. Atkins. Between us we started to evolve what is now the Mushroom Industry's own research station.

Presently we and a few others were faced with expenditure on a very much larger scale than had entered into our calculations. Still we persisted and we did find the money to employ our scientific staff, build and re-build our laboratory and growing sheds. All this involved a great strain on our financial resources, since shares ranged from £500 to £150 a year.

This was all very well for a limited period, but quite obviously only the exceptionally high prices for mushrooms ruling during those years made it possible. Gradually, therefore, as prices declined and costs rose, it was borne in upon us founder members that such expenditure was no longer possible.

In 1948 it became clear that either the Research Association would have to be liquidated or handed over in some form to the Government and private enterprise.

I had felt very strongly that our efforts and our money would be wasted if we did hand over to the Industry, but I acknowledge that I was wrong. It had become the only course of action open and there is now no doubt whatever that the station will live and benefit the whole industry in a thousand ways.

In writing this preface I am sure I voice the feeling of all the original members when I say that one and all of us wish the Association every possible success and that we feel our part in founding it is not forgotten. It was a heavy burden financially, but one that has been well worth while, the more especially if it has done anything to benefit the ex-Service grower.

C. P. WHITAKER,

Chairman, 1945-1948.

The main laboratory.

STAFF

Director of Research :

R. L. EDWARDS, PH.D., B.SC., F.R.I.C.

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C. J. LA TOUCHE, M.SC., H.DIP.ED., L.A.H.—to October, 1948
MISS C. W. H. DUNCAN, B.SC.—from November, 1948

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Assistants :

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MISS I. WARMAN
MISS P. BARROWS
J. HOLLAND
E. SIMPSON—from November, 1948

Secretary :

MISS R. K. HALBARD—to February, 1948
MISS J. E. P. HILL—from March, 1948

Foreman :

G. R. BROWN

Assistant :

E. YARROW—to April, 1947
D. EATON—from March, 1947

INTRODUCTION

This is the first public Report of the Mushroom Research Station, and it is appropriate to describe briefly the events which led to its formation.

Mushroom growing had been very much restricted during the period 1939-1945 owing to war conditions, and when growers wished to resume their pre-war scale of operations in 1945 they found that among other problems they were faced with a dwindling supply of good quality manure. Several specialists who had formed the Midlands Group of Mushroom Growers, in an effort to improve conditions generally, decided that one of their most urgent needs was for research on this problem on an adequate scale without delay. They saw little prospect of such work being undertaken in existing research stations, and accordingly they formed the Mushroom Research Association with its own research station to study this and other problems.

The Research Association was open to all commercial mushroom growers who would pay annual subscriptions proportional to their cultivated area of mushroom beds. About 25 growers joined, and the research station was maintained as a private institution by the members from its formation early in 1946 until the end of 1948. By that time it was clear that the number of growers willing to subscribe on this basis was small, and that their individual contributions must be large and would eventually form too great a burden, in view of the post-war fall in mushroom prices.

The Mushroom Growers' Association had made repeated requests to the Government for immediate research on a national scale, and had been promised that this would be included in the programme of the projected glasshouse research station.

The members of the Research Association wished their research station to continue its work even though they might not be able to support it indefinitely without help. Accordingly, negotiations were started between the Growers' Association and the Research Association leading to an approach to the Government for a grant towards the future maintenance of the station. It was then agreed that the Ministry would make such a grant and the Growers' Association would make every effort to secure support for the research station, on the condition that all past and future work would be published. Although the Research Association from 1946 to 1948 was a private organisation, and all results were the property of its members, some notes of scientific interest and some general articles on current mushroom problems had been published by members of its staff, and these are given in the list of publications later in this Report.

The Research Station

The research station at Yaxley is built on a site of three acres adjoining a main road and railway station. The sub-soil is quite satisfactory for casing mushroom beds.

The first wooden laboratory building, the only kind for which a building licence could be obtained, was completed in September, 1946. This was almost completely destroyed by fire in December, 1947, with

most of the apparatus and equipment. Some of the pure cultures and nearly all of the experimental records were saved. In July, 1948, a new laboratory was completed on the same foundations. During the intervening period the British Sugar Corporation Limited very kindly provided laboratory facilities which minimised the interruption to laboratory work.

The new laboratory is a substantial brick building with several rooms, all on one floor. The main laboratory is equipped for chemical research and analysis with electric drying ovens, a furnace, pH meter, centrifuge, Spekker absorptiometer for colorimetric analysis, and the usual balances, glassware, etc. The microbiological laboratory has a good microscope, four incubators, a sterile chamber for handling cultures, a microtome and apparatus for culture work. There are also a store, balance room, library and office.

The turning shed is fitted with a row of partitions along each side forming separate bays in which 24 composts can be stacked. In this way 24 small stacks of $\frac{1}{2}$-ton can be made with little more exposed surface than would be normal in a single 12 ton stack, and the aeration, heating, and drying conditions which are so important in composting are very similar to those found in commercial practice. This is a necessary condition for successful experiment and for application of the results obtained.

The two test houses are double-walled asbestos structures 36′ × 18′ inter-lined with double aluminium foil, on concrete floors. Each is fitted with six shelves and each shelf can be divided into 12 beds, making 72 beds of 10 sq. ft. There is room for small trays under the bottom shelves.

PROGRAMME

The original subscribers considered that their most urgent need was for a synthetic compost to replace horse manure. It was estimated that an adequate study of this problem, whether successful or not, might occupy anything from three to ten years, and it was impossible to predict what supplies of horse manure would be available during that time. Attention was, therefore, concentrated on the study of composts and particularly on the supplement needed to convert wheat straw into an adequate substitute for horse manure.

There were four main lines of approach to this problem, though naturally they were inter-related :

Analysis of horse manure and prepared composts at each stage up to the end of the mushroom crop.

Laboratory study of the nutritional requirements of the mushroom in artificial culture.

Study of the micro-organisms active during composting of horse manure, and in straw composts.

Small scale cropping experiments carried out under conditions as closely related to commercial mushroom growing as possible.

Some previous work had been done on each of these subjects using a variety of methods. Most of 1946 was spent reviewing this work and in preparations for the experimental programme reported here.

The progress made with these four lines of investigation has varied considerably. Many analyses of mushroom composts have been made and some of them have been related to the composting process and the mushroom crop. Progress with the mushroom in pure culture has been slow. Mushroom mycelium is slow growing and erratic in its behaviour when quantitative results are wanted, and although certain aspects of this work are still in progress it has not made the contribution which was expected towards the main problem. Small scale composts have been made in groups of 12 and later of 24 stacks which could be prepared under conditions similar to those of a large stack, and these have given results sufficiently reproducible to determine the main requirements for nitrogen, phosphorus and potassium in artificial straw composts. All these experiments are statistically analysed and the standard error of each mean result is given.

It was appreciated from the start of this work that there are enormous gaps in our knowledge of the behaviour of the mushroom as a fruiting organism ; continual efforts have been made to use the crop records, and to include other observations on the experimental beds, to learn something of the fundamental biology of the mushroom. Among other things a relation between the number and size of mushrooms produced has often been observed and some factors in the compost have been found to affect independently the time of fruiting, the number of mushrooms produced, and their size.

This programme has involved the development of new and improved methods of analysis and microbiological technique, and has brought its own problems in the statistical treatment of the mushroom cropping experiments. Incidentally, observations have been made as opportunities occurred on some of the fungi which grow in compost or cause disease in the mushroom.

Acknowledgment is due to all the original members of the Research Association for the way in which they placed their knowledge, their farms and their crop records at the disposal of the staff, and particularly to Messrs. Noble Mushrooms Ltd., and to Mr. B. A. Noble for advice on cultural problems. Our greatest debt is to Mr. F. C. Atkins for his invaluable help and advice at all times.

Advisory Services

One of the original objects of the Association was to provide scientific advice on the ordinary problems of growers. To be complete, this would have to cover two distinct requirements, a laboratory service for the examination of materials submitted by members, and a field service by which members of the staff would visit and advise the grower on request. With the limited staff and funds available this could not be done, but members have sent in samples of diseased mushrooms, infected compost, or casing soil for identification of the causal organisms and advice on treatment.

Composting shed divided into bays containing separate stacks of compost. A portable pH meter is being used with spear-type electrodes.

Experimental mushroom house showing the division into small beds.

CROPPING EXPERIMENTS — R. L. Edwards

In planning a series of cropping experiments it was clear that enough beds must be used for adequate replication of the experimental treatments. Factorial experiments were considered the most efficient standard type for a systematic study of mushroom nutrition on this scale, particularly in view of suggestions in the literature that the requirements for some of the main nutrients are inter-related. These experiments would need a substantial number of batches of compost and beds. One experiment was started in July, 1946, with 3 stacks of horse manure, mainly to obtain general information about experimental conditions. In 1947-48 eight further experiments were started with synthetic composts based on wheat straw, and seven were completed, one continuing into 1949. In these nine experiments 112 batches of compost were made, and 408 beds of 10 or 20 sq. ft. and 118 trays of 3 or 4 sq. ft. were cropped and separately recorded. In addition, one batch of horse manure compost was provided by Messrs. Noble Mushrooms Ltd. for a tray experiment, and six trays filled with synthetic compost from Experiment 6 were taken over and cropped by them.

The process of composting depends very largely on the retention of heat in the fermenting stack and on its moisture content and aeration. An attempt was made to reproduce as closely as possible the conditions in a commercial stack, by placing the small experimental stacks side by side, separated by iron sheets. The general effect was that of cutting one long stack into slices without affecting its heat and water losses and aeration.

Each stack is made up, turned, and filled into beds on the same day in succeeding weeks, so that there are seven-day intervals between all these operations. There is some variation in the numbering of turns among different growers. We stack our compost and give it the first turn a week later. Filling "at the fifth turn" means that after five weeks composting the stack is shaken out as usual but instead of being restacked, the compost is bagged up and carried into the test house where the beds are made.

The progress of fermentation, temperature readings which were taken daily during some experiments, and the cropping results show that commercial growing conditions are being substantially achieved. Some uncontrolled differences remain, as shown by significant differences between pairs of stacks of identical composition in some experiments. The existence of such differences was suspected in the first factorial experiment and was provided for in all later ones by replicating stacks as well as beds. This introduced the concept, unusual in agricultural experiments, of two independent sources of error, each capable of estimation, and each having a definite physical basis. Three or more beds are filled from each stack of compost, and in some experiments groups of beds receive different treatments in the house. In comparisons between treatments applied to stacks of compost the standard error quoted is that between stacks, for the number of stacks in the experiment. In respect of bed treatments the inter-bed error and number of

beds are used. The number of observations represented by the mean also affects its standard error. Thus there may be, as in Experiment 5, quite different standard errors for different kinds of treatment in the same experiment. This very important subject will be discussed more fully in another publication. Any difference between two averages which is less than twice their standard error might be due to chance variations between similarly treated beds. Any difference greater than this is regarded as probably significant, and if greater than three times the standard error it is highly significant.

Our thanks are due to Mr. E. C. Fieller for his valuable advice on the statistical treatment of the cropping experiments.

Apart from the special requirements of each experiment the cropping houses are managed on normal commercial lines. In all experiments the number and weight of mushrooms are recorded for each bed at each picking. The dates of first picking and of flushes, and the productive life of each bed are also recorded. In the course of these experiments some observations on the relation between size and weight of mushrooms at various stages, their rate of growth on the bed, and the relation between number and size, have been made.

For the convenience of growers temperatures in this part of the Report are given in degrees Fahrenheit.

John Donne said that comparisons are odious. This is certainly true of mushroom yields, except within the limits of a controlled experiment, for growing conditions, materials, labour, and weather are rarely the same for different farms or even for crops on one farm. However, nothing will stop growers comparing their yields, and a note about the basis on which our experimental yields should be judged is desirable. In each experiment it is to be expected that there will be some good and some bad yields, the object being to determine which compost or other treatment gives the best result. Often some of them are total failures, and indeed that is sometimes expected. Under these circumstances the average yield from the whole house is not a fair estimate of its performance. The best bed is equally unsatisfactory, and if a figure is wanted for comparison with horse manure or other composts, it should be the average of all the beds receiving the best combination of treatments. This figure is given for each crop in this report, but too much importance should not be attached to it because all experiments are intended to measure differences within one house. Getting the maximum yield from the whole house or from any one treatment is of secondary importance, however gratifying it may be when a good yield is obtained.

Experiment No. 1

The objects of this experiment were to study :—

1. the effect of adding gypsum or ground limestone to a horse manure compost,
2. the effect of varying the depth of the beds within the range 5 to 9 inches,
3. the effect of spawning at 8 inch and 12 inch intervals,
4. the degree of variation likely to occur in replicated experiments under our conditions.

The addition of 28 lbs. of gypsum per ton of manure is established as a useful practice as a result of Pizer's (1936-38) work. A threatened shortage of gypsum at the time of this experiment made a search for possible alternatives desirable.

The only reported work on the effect of varying depth is an inconclusive experiment by Bewley (1938) with 4″ beds. There are no reliable reports on the effect of varying the rate of spawning. Apart from its possible value in commercial growing, information on these points was desirable as a guide for future experiments.

The only full report on systematic replicated growth tests with mushrooms is that of Lambert (1934). He used beds varying from 10 to 40 sq. ft. and found considerable differences in variance between three farms. He found 20 sq. ft. the best unit area, and under his best conditions a difference in yield of 10% was necessary to establish a significant difference in an experiment with 5 beds on each experimental treatment (5 replications).

12 tons of horse manure were stacked with $10\frac{1}{2}$ cwt. of straw, soaked before use by a continuous drip-pipe. At the second turn the manure was divided into three equal parts. Ground limestone was added to one and gypsum to another, at 28 lb. per ton. A week after the fourth turn twelve beds were filled from each stack.

The house had two blocks of 3 shelves, each shelf being divided into 6 beds of 20 sq. ft. The whole of one shelf was taken as a unit for variations in spawn rate, half the shelf being deep and half shallow, with three different composts in each half shelf. Spawn rate, depth, and compost were allocated at random within this system.

The interval from spawning to picking and the weight, number, and size of mushrooms picked are summarised in Tables 1-4.

Gypsum and Ground Limestone

The gypsum compost gave a more rapid spawn run, slightly earlier mushrooms, and a heavier crop in the first 4 weeks. The rate of cropping was about equal for the next 6 weeks, but after that the gypsum beds were less productive, and at 16 weeks the total crops on all three composts were equal. The gypsum beds also produced more mushrooms than did the others, particularly in the first 4 weeks; this difference was not completely wiped out, and the gypsum beds were still ahead on numbers after 16 weeks.

Depth

The deep beds were 4-6 days earlier in production, possibly due to better temperature conditions, but this advantage was soon lost and the numbers produced by deep and shallow beds were equal at all times from 4 to 12 weeks. After that the shallow beds began to fall behind, and from 12 to 16 weeks the deep beds were more productive. Throughout the house deep beds produced heavier mushrooms, and therefore greater total yields, than those picked from the corresponding shallow beds. The increase in weight was not quite proportional to the depth, and the shallow beds produced heavier crops per ton of manure.

Table 1—Interval from spawning to first picking

	days		s.e.
Plain compost	71		
Limestone compost	70	±	0·6
Gypsum compost	68		
Deep beds	67		
Shallow beds	72	±	0·5
8″ spawn rate	69		
12″ ,, ,,	71	±	0·5

Table 2—Yield, lb. per sq. ft.

	4 weeks	8 weeks	12 weeks	16 weeks	20 weeks
Plain compost	0·3	0·8	1·3	1·6	1·8
Limestone ,,	0·3	0·9	1·3	1·7	1·8
Gypsum ,,	0·6	1·1	1·5	1·7	1·8
Deep beds	0·4	1·0	1·5	1·9	2·1
Shallow beds	0·3	0·8	1·2	1·4	1·6
8″ spawn rate	0·4	1·0	1·4	1·7	1·8
12″ ,, ,,	0·3	0·8	1·3	1·7	1·8
Standard error of means	± 0·023	± 0·04	± 0·06	± 0·07	

Table 3—Mushrooms per sq. ft.

	4 weeks	8 weeks	12 weeks	16 weeks
Plain compost	8	23	37	49
Limestone ,,	7	23	37	50
Gypsum ,,	20	40	53	62
Deep beds	12	29	43	57
Shallow beds	11	29	42	51
8″ spawn rate	14	33	45	55
12″ ,, ,,	9	25	39	55

Table 4—Average size, oz. per mushroom

	4 weeks	8 weeks	12 weeks	16 weeks
Plain compost	0·60	0·56	0·56	0·52
Limestone ,, ...	0·69	0·62	0·56	0·54
Gypsum ,, ...	0·48	0.44	0·45	0·44
Deep beds	0·53	0·55	0·56	0·54
Shallow beds	0·44	0·46	0·46	0·44
8″ spawn rate	0·46	0·48	0·50	0·50
12″ ,, ,, ...	0·53	0·51	0·53	0·50

Rate of Spawning

The beds spawned at 8″ intervals produced their first mushrooms an average of 2 days before the beds spawned 12″ apart. The pieces of spawn used were approximately the same size in all cases. The 8″ spawned beds produced more mushrooms and a heavier total crop for the first 8 weeks, but then the 12″ spawned beds began to catch up, and at 16 weeks there was no difference in total numbers or in total crop. Owing to the inverse relation between weight and number of mushrooms mentioned later, the 12″ beds produced the heavier mushrooms in the first few weeks, and the yields were equal in the period from 4 to 8 weeks. After that the 12″ spawned beds gave heavier crops, until the total crops were equal after 16 weeks.

Average Size of Mushrooms

On composts of the same depth there was an inverse relation between the number of mushrooms per sq. ft. and their average weight. There was also an inverse relation between the number in a flush and their average weight. This was particularly marked on the gypsum and deep limestone treated beds.

Degree of variation

The total yields at 4, 8, 12 and 16 weeks, have been subjected to statistical analysis (Fisher, 1946), and the results are shown in Table 5. This analysis established the significance of the main conclusions already stated. It also showed that with this experimental design, in which 24 or 36 beds contributed to each comparison to be made, there was a significant difference between any two treatments which gave yields differing by 5-6% (less than 0·1 lb. per sq. ft. at 8-16 weeks). This was very satisfactory and was promising for future trials of experimental composts.

Table 5—Analyses of variance

Variance (lb. per bed of 20 sq. ft.)				
Period	4 weeks	8 weeks	12 weeks	16 weeks
Between composts (C)	171	206	175	102
,, depths (D)	32	144	428	765
,, spawn rates (S)	106	100	29	0
Interaction C × D	1·5	2	0	6
,, C × S	0·5	1·5	1·5	2
,, D × S	14	3	0	4
,, C × D × S	6·5	10	13·5	21
Error	2·6	8	17·6	23·7
Standard error of 1 bed (lb. per 20 sq. ft.)	1·6	2·8	4·2	4·9
St. error lb. per sq. ft.....	0·08	0·14	0·21	0·24
As % of av. yield	21	15	16	15

Occurrence of Flushes

It is generally recognised that cultivated mushrooms develop in flushes at intervals which vary according to the conditions of growth.

The number, weight and average size of mushrooms in each flush on each bed were recorded, together with the duration of the flush (no. of days picking), interval from the end of one flush to the start of the next (blank period), and interval between the middle days of successive flushes (phase length), this being the best measure of the true interval between flushes. (Tables 6 and 7.)

There appears to be no clear relation between any of these times and the total yield, number or size of mushrooms in the individual flushes.

The average duration of a flush on deep beds was longer than on shallow ones, and on limestone compost it was longer than on either of the other composts. These differences may be significant, but their full intrepretation is at present uncertain. One possible reason for them was revealed by an examination of the titration curves of these composts (Diagram 6). These showed that the limestone compost has much greater buffering power than either of the other composts. If acid production, which does occur in mushroom beds as shown by the fall in pH during cropping, is one of the factors contributing to end a flush, greater buffering power would tend to lengthen the flushes. Comparing deep with shallow beds there is a quantitative difference in buffering power per sq. ft. of bed surface, by virtue of the depth. It has already been shown that fruiting is a surface phenomenon as regards number of mushrooms, and the weight produced per lb. of compost is greater in shallow beds. There is thus more compost in deep beds to

absorb and neutralise any acid produced, whether this is quantitatively related to the number or weight of mushrooms. This is only a tentative hypothesis to explain one of the many interesting observations made in the course of these experiments.

Table 6—Flushes on main treatments

Group	Average Duration	s.e.	Blank Interval	Phase length
	days		days	days
Plain compost	6·4	± 0·5	8·2	15·7
Limestone ,, ...	7·4		7·0	15·3
Gypsum ,, ...	6·5		8·7	16·0
Deep beds	7·2	± 0·4	7·9	15·9
Shallow beds	6·4		8·0	15·4
8″ spawn rate	6·9	± 0·4	8·0	15·5
12″ ,, ,, ...	6·7		8·0	15·8

Table 7—Duration and frequency of successive flushes

Flush	Average duration	Blank interval	Phase length
	days	days	days
2nd	7·5	4·2	13·3
3rd	7·5	6·8	15·0
4th	6·4	8·6	16·0
5th	5·9	9·8	17·1
6th	6·4	8·6	15·2
7th	6·8	9·9	17·5

Conclusions

Ground limestone does not replace gypsum as a promoter of spawn growth.

In this compost gypsum had an early beneficial effect on spawn run and cropping, but it did not give a greater total yield after 20 weeks.

Increasing the depth of the beds by 50%, other things being unchanged, gave heavier mushrooms and a bigger crop per sq. ft.

Shallow beds gave a heavier crop per ton of manure than did deeper beds.

Spawning at 8″ intervals gave a bigger crop in the first few weeks but beds spawned at 12″ intervals drew level after 14-16 weeks.

The failure of ground limestone to replace gypsum and the effect of depth are probably of general application. The effect of gypsum and spawn rate, particularly with regard to the times at which they were effective, might be different in other composts.

Experiment No. 2

This experiment was intended to compare dried blood (organic) and a mixture of ammonium sulphate and nitrochalk (inorganic) as sources of nitrogen : the effect of adding two different mixtures, S and T, of mineral salts derived from papers by Stoller (1941) and Treschow (1944) : the effect of adding soil to the compost.

One stack was made with each of the twelve possible combinations of nitrogen, soil, and trace elements shown in Tables 8 and 9.

Each stack also contained 27·5 lb. of potassium sulphate, 9 lb. of superphosphate, and 5 lb. of calcium carbonate per ton of straw.

Table 8—Supplements per ton of straw

Nitrogen		Soil	Trace elements (see Table)
Dried blood	250 lb.	Soil 2 cwt.	Salt mixture S
Calcium carbonate	45 lb.	or	or
or		No soil	Salt mixture T
Ammonium sulphate	75 lb.		or
Nitrochalk	110 lb.		No salt mixture

Table 9—Salt Mixture S per ton of straw

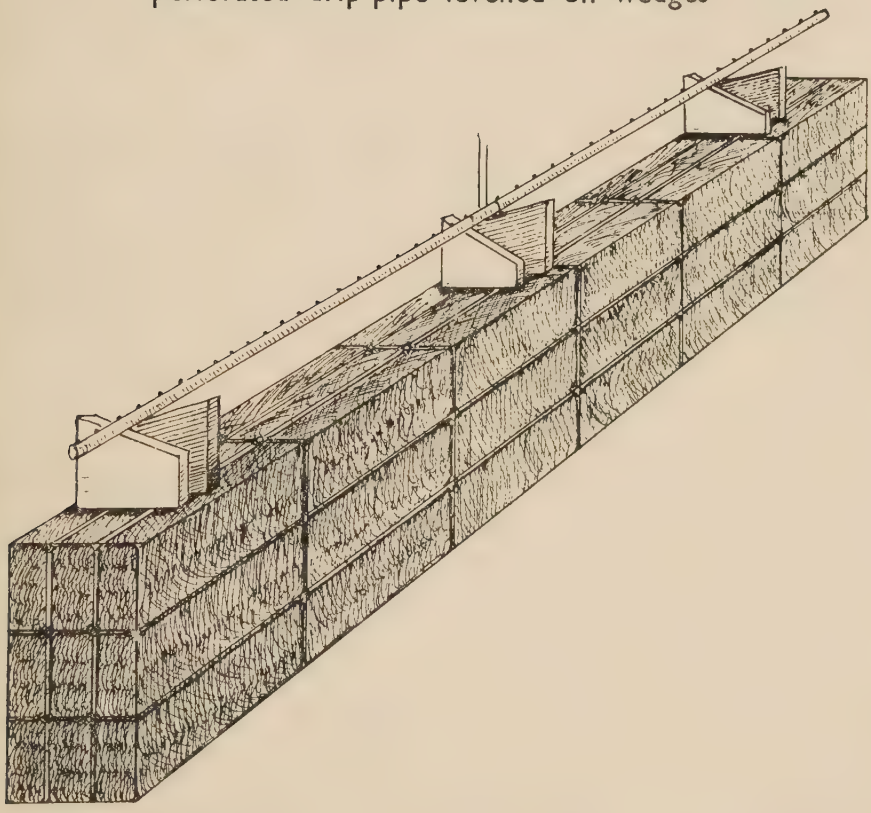
	lb.	oz.
Manganese sulphate	5	10
Ferrous sulphate	2	13
Aluminium sulphate		10
Copper sulphate		10
Zinc sulphate		5
Basic chromium sulphate		$2\frac{1}{2}$
Boric acid		5
Potassium bromide		$1\frac{1}{4}$
Potassium iodide		$\frac{1}{3}$

Table 9 (contd.)—Salt Mixture T per ton of straw

	lb.	oz.
Manganese sulphate		$\frac{1}{6}$
Ferrous sulphate		$\frac{1}{6}$
Copper sulphate		$\frac{1}{6}$
Zinc sulphate		$\frac{1}{6}$
Magnesium sulphate	4	6

DIAGRAM 1

Wetting Bales of Straw by means of a perforated drip-pipe levelled on wedges



The bales of straw, five for each stack, were wetted by means of a drip-pipe devised by Messrs. Noble Mushrooms Ltd. The straw was shaken out, watered where necessary, and stacked, the mixed chemicals being added between layers of straw a few inches thick. The stacks were trodden continuously to make them compact.

The composts heated up normally ; they were turned after 10 days and then at weekly intervals. A week after the 4th turn they were shaken out and made into beds, 3 beds of 20 sq. ft. being filled from each compost. Each bed contained 255 lb. of compost containing 50 lb. of dry matter. The house was heated up to 100° F. for 24 hours. The beds were then spawned and were cased 10 days later. The composts were made wet and cased early to minimise drying out which seems to be one of the characteristics of synthetic straw composts. In the light of subsequent experience these composts may have been too wet.

The average intervals from spawning to appearance of the first pinheads for each group of three beds are shown in Table 10.

Table 11 gives the average number and size of mushrooms and the average yield after 12 weeks picking on each bed.

There was no replication of stacks in this experiment and the standard errors are those between beds. From other experiments the stack errors can be estimated as about three times greater.

The best average yield from a group of three beds was 1·3 lb. per sq. ft., from the compost with dried blood—salts S—no soil.

Table 10—Days from spawning to first pinheads

	Inorg. N.	Org. N.	s.e.
With soil	55	45	± 2·3
No soil	44	54	
Salts S	39		
Salts T	46		± 2·0
No salts	62		

Table 11—Yields after 12 weeks

	Mushrooms per sq. ft.	s.e.	lb. per sq. ft.	s.e.	oz. per mushroom
Dried blood	18	± 1	0·9	± 0·03	0·8
Inorganic N	10		0·5		0·8
No salts	17		0·7		0·7
Salts S	17	± 1·3	1·0	± 0·03	0·9
Salts T	8		0·4		0·8
With soil	14	± 1	0·7	± 0·03	0·8
No soil	15		0·7		0·7

Conclusions

Dried blood produced more mushrooms and greater total yield than the inorganic nitrogen composts.

Salts S produced the earliest and largest crop.

The addition of soil to the compost delayed fruiting with inorganic nitrogen, but with dried blood soil advanced fruiting.

Salts S have a marked effect in maintaining production towards the end of the crop, when the other composts were fading out.

Experiment No. 3

This experiment was arranged to compare three levels of nitrogen, supplied as dried blood, and three levels of superphosphate.

Half of the composts had all the phosphate added at the start, in the other half part of it was added when the compost was shaken out for filling. The results show quite a marked response to the later addition of phosphate.

This was the first experiment in which composts were duplicated. Previously three identical beds had been filled from each compost, giving a check on inter-bed variations, but we had no such check on uncontrolled variations at the composting stage.

The stacks were made up with two levels of superphosphate and three of dried blood, giving six possible mixtures. Two stacks were made with each of these, as shown in Table 12. Each stack was divided into two parts a week after the 4th turn, the 'A' part being put straight into the beds. The 'B' part had additional superphosphate added and was then put into the beds. Three beds of 10 sq. ft. each were filled from each half stack, making 72 beds in all.

Table 12—Nitrogen and phosphate treatments

	Dried blood, lb. per ton of dry straw			
	110	260	410	
Super-phosphate added at stacking	N_1P_1 36 N_1P_2 106	N_2P_1 33 N_2P_2 103	N_3P_1 30 N_3P_2 100	lb. per ton of dry straw
Superphosphate 70 lb. per ton added at filling to half of each stack	N_1P_1+P N_1P_2+P	N_2P_1+P N_2P_2+P	N_3P_1+P N_3P_2+P	

Observations During Composting

3 ft. iron pipes were driven into each stack and temperatures were taken daily by dropping a laboratory thermometer down each pipe. From these records the maximum and the average temperature in each stack after each turn were calculated. The averages of these for the main factors are given in Table 13. There are significant differences between the three levels of N, but the effect of additional superphosphate was not significant. The date of appearance of pinheads was recorded and is summarised in Table 14. Cropping was strongly advanced by high N (N_2 and N_3) and slightly by adding superphosphate to the low P stacks at filling. If confirmed this supports an earlier report by Pizer.

Table 13—Maximum compost temperatures

N_1	135° F.	± s.e. 1·8° F.
N_2	142° F.	
N_3	147° F.	
P_1	140° F.	± s.e. 1·7° F.
P_2	143° F.	

Table 14—Average days from spawning to appearance of first pinheads

N_1	72	± s.e. 2·3	
N_2	52		
N_3	49		
		P_1	59
		P_1 + P	50
		P_2	57
		P_2 + P	63
			± s.e. 2·7

Table 15—Days from first to last picking

N_1	65	± s.e. 3·5	
N_2	81		
N_3	93		
		P_1	85
		P_1 + P	88
		P_2	75
		P_2 + P	70
			± s.e. 4·0

The experiment was continued until all the beds appeared to be exhausted, and cropping ceased. Table 15 shows the average duration of picking for each treatment. High nitrogen and low phosphate gave the longest picking period.

Yields

As usual we recorded the number and weight picked from each bed and calculated the average weight per mushroom. Table 16 shows these data summarised by treatments.

The proportion of nitrogen had a slight but not significant effect on the number of mushrooms produced; it had more effect on the average weight per mushroom, and hence on the total yield, which was significantly increased by high nitrogen. The proportion and time of adding phosphate affected the number and yield by weight, but not the average weight per mushroom. The addition of half of the phosphate at the end of composting gave better yields than did adding all of it at the start, at the P_2 level.

Analyses reported on p. 49 show that the high nitrogen composts have lost relatively more nitrogen than have the lower ones.

Table 16—Yields after 12 weeks

	lb. per sq. ft.	Number per sq. ft.	oz. per mushroom
N_1	·54	12·3	0·7
N_2	·63 ± s.e. ·14	12·4 ± s.e 3·0	0·8
N_3	·85	15·4	0·9
P_1	·95	19·2	0·8
P_1 + P	·82 ± s.e. ·17	16·1 ± s.e. 3·5	0·8
P_2	·58	11·4	0.8
P_2 + P	·33	6·8	0·8

It is dangerous to compare the size of mushrooms in different crops, but we found that these synthetic composts gave considerably larger mushrooms than those picked during our first experiment with horse manure. In this experiment size increased with the nitrogen content of the compost, and the greater size of mushrooms on synthetic composts may be due to their greater nitrogen content. Although much nitrogen is lost at the higher levels, it is not completely wasted.

Conclusions

In the range of nitrogen and phosphate levels tested, raising the nitrogen increased the size and total crop of mushrooms, but not their number, and gave earlier and more prolonged cropping.

Raising the phosphate depressed the numbers and total yield, without affecting size, and shortened the cropping period.

The addition of some superphosphate at the end of composting instead of at the beginning caused earlier cropping, and increased the numbers and total yield.

Experiment No. 4

The experiment was arranged to compare nitrochalk (inorganic) with dried blood (organic) as sole source of nitrogen, combined with three levels of potash, supplied as potassium sulphate.

Twelve stacks were made, two with each of the six combinations thus formed as shown in Table 17.

Table 17

		Source of nitrogen per ton of straw	
		100 lb. dried blood (O)	100 lb. nitrochalk (I)
Potassium sulphate lb. per ton of straw	K_1	14	14
	K_2	63	63
	K_3	112	112

Table 18—Mean values of maximum compost temperatures

Dried blood	143° F.	± s.e. 1·4° F.
Nitrochalk	138° F.	
K_1	143° F.	± s.e. 1·8° F.
K_2	142° F.	
K_3	140° F.	

Table 19—Interval between spawning and first picking, days

	Dried blood	Nitrochalk	Mean
K_1	94	127	110
K_2	102	120 ± s.e. 8	111 ± s.e. 6
K_3	96	144	120
Mean	97	130 ± s.e. 4	

Table 20—Yield, oz. per sq. ft.

	Dried blood	Nitrochalk	Mean
K_1	13	1	7
K_2	9	3 ± s.e. 2	6 ± s.e. 1·5
K_3	5	5	5
Mean	9	3 ± s.e. 1·2	

The best group of three beds produced 0·8 lb. per sq. ft.

Table 21—Number of mushrooms per sq. ft.

	Dried blood	Nitrochalk	Mean
K_1	18	1	9
K_2	13	4 ± s.e. 3	8 ± s.e. 2
K_3	6	7	6
Mean	12	4 ± s.e. 2	

Table 18 gives the mean of the maximum temperatures observed between turns in each stack, Table 19 the intervals from spawning to production, and Tables 20-22 the yield, number and average size of mushrooms picked.

Table 22—Average size, oz. per mushroom

	Dried blood	Nitrochalk	Mean
K_1	0·7	0·6	0·7
K_2	0·7	0·8	0·7
K_3	0·8	0·8	0·8
Mean	0·7	0·8	

The dried blood composts were hotter than those containing nitrochalk. The lowest level of potash gave the highest temperatures.

All the yields were low and cropping was slow, possibly because all the composts contained too much phosphate. (This experiment was started while the previous one on phosphate requirement was still in progress.)

Conclusions

Dried blood proved greatly superior to nitrochalk as a source of nitrogen.

The potassium requirement varied with the source of nitrogen used, dried blood requiring low, and nitrochalk high potassium.

Experiment No. 5

Two mixtures of dried blood and nitrochalk were used in an attempt to reduce the cost of the synthetic compost. In its present form dried blood is the main and most expensive constituent.

The use of organic materials other than straw is commonly advised, but most of the materials used in U.S.A. are not available to British growers. Sugar beet tailings are the pieces trimmed from the beet after washing and before slicing. They are available in large quantities at all sugar beet factories where they are dumped and allowed to rot down to a humic residue over a period of several years. They are rich enough in available carbo-hydrate to ferment spontaneously with considerable heat production.

Oilseed residues have been recommended in the French literature and by Bewley, but most of them are now rationed animal feeding stuffs. Castor bean meal, the residue from extraction of castor oil, contains a poisonous alkaloid, and is not used for feeding. It contains 5% of nitrogen.

Twelve composts were made in two blocks of the six combinations shown in Table 23.

Temperatures were recorded daily, and the maximum temperatures reached in each weekly period are compared in Table 24.

Table 23

	75% dried blood 25% nitrochalk	25% dried blood 75% nitrochalk
Supplements per ton of straw	none	none
	2 cwt. sugar beet tailings	2 cwt. sugar beet tailings
	56 lb. castor bean meal	56 lb. castor bean meal

Table 24

	Av. max. temp. °F.
75% blood	138
75% nitrochalk....	131 } ± s.e. 1 deg. F.
No supplement	135
Beet tailings	134 ± s.e. 1 deg. F.
Castor bean meal	136

Composts with the higher proportion of dried blood gave the highest temperatures. There was no significant difference due to beet tailings or castor bean meal.

After filling and spawning a further experimental treatment was introduced. We had noticed that synthetic composts in our houses become very dry on the surface. In an attempt to prevent this the beds on one side of the house were very lightly misted over twice weekly from spawning to casing. Only enough water was applied to moisten the surface of the compost. There was never enough water to run down into the beds. This treatment stopped when the beds were cased two weeks after spawning.

Table 25 – Average days from spawning to first picking

	75% dried blood	75% nitrochalk
No supplement	80	99
Beet tailings	77	71 } ± s.e. 7
Castor bean meal....	80	96
Beds sprayed	89	
Beds not sprayed....	81 } ± s.e.1·3	

The date of first picking was significantly affected by several factors as shown in Table 25. The beds came into crop in July, the interval after spawning being in May and June.

The final yields in lb. per sq. ft. are given in Table 26, the number per sq. ft. in Table 27, and average sizes in Table 28.

Table 26—Final yields (lb. per sq. ft.)

	75% blood	75% nitrochalk	Mean
No supplement	1·2	0·6	0·9
Beet tailings	1·2	1·2 ± s.e. 0·35	1·2 ± s.e. 0·25
Castor bean meal	1·4	0·9	1·2
Beds sprayed	1·0	0·8	0·9
Beds not sprayed	1·6	1·0 ± s.e. 0·1	1·3 ± s.e 0·07
All treatments	1·3	0·9 ± s.e. 0.2	1·1

The best group of three beds averaged 2·1 lb./sq. ft.

Table 27—Mushrooms per sq. ft.

	75% blood	75% nitrochalk	Mean
No supplement	16	5	11
Beet tailings	17	17 ± s.e. 7	17 ± s.e. 5
Castor bean meal	21	8	4
Beds sprayed	11	9	10
Beds not sprayed	25	12 ± s.e. 1·2	18 ± s.e. 1·0
All treatments	18	10 ± s.e. 4	14

Table 28—Average size, oz. per mushroom

	75% blood	75% nitrochalk	Mean
No supplement	1·2	1·9	1·4
Beet tailings	1·2	1·1	1·2
Castor bean meal	1·1	1·7	1·3
Beds sprayed	1·4	1·4	1·4
Beds not sprayed	1·0	1·3	1·2
All treatments	1·2	1·4	1·3

Sugar beet tailings made no difference to the 75% blood composts, but greatly increased the number of mushrooms and total yield on the 75% nitro-chalk composts. The increase in numbers was so great that a reduction in size of the individual mushrooms was to be expected. This is worth further investigation.

The result of spraying the beds between spawning and casing was a complete surprise. The adverse effect is unmistakable, but it should not at this stage be regarded as applying to all other composts. It may not even apply to other types of house or other seasons of the year. These reservations are made for the following reasons. Our test houses are rather more airy than most mushroom houses and the ratio of air space to bed is high. Beds of synthetic compost become very dry on the surface, and even the lightest watering must produce locally quite a drastic temporary change in conditions. If drying was less marked, because of greater humidity in the air or retention of moisture by the compost, the shock due to a similar amount of water would be milder, and the effect on cropping might be less. The only general conclusion is that there is no evidence in favour of this practice.

Conclusions

A mixture of dried blood and nitrochalk in the ratio 3 : 1 was superior to the 1 : 3 mixture as a source of nitrogen, confirming previous observations on the value of dried blood.

Castor bean meal raised the yield.

Sugar beet tailings raised the yield from high nitrochalk composts to equal that obtained from composts richer in dried blood.

Spraying the surface of the beds very lightly twice a week between spawning and casing greatly reduced the yield.

Tests on Growth Substances

There is an old-established belief among mushroom growers that manure from stallions gives heavier crops than that from geldings. With increasing knowledge of the existence of sex hormones it was natural to attribute the superior quality of stallion manure to their presence. Other growth substances are now known to be essential for many other fungi, and Treschow (1944) obtained increased crops by adding aneurin, biotin, and nicotinic acid to his compost. Investigation and application of these reports is made difficult by the probability that they depend on the varying composition of the basal compost. One stack may give an increase in yield on addition of aneurin, in which it was previously deficient, while another stack, outwardly similar, but having plenty of aneurin, would be unaffected by adding it.

However, the possibilities were so great that a start was made by testing a wide range of substances, each sprayed on four small trays filled with composts from Experiment 2 before casing. Untreated trays were filled with each of the composts used. The most notable results are summarised in Table 29.

Calcium pantothenate advanced the appearance of mushrooms on two composts by 7 and 9 days respectively, the duplicate trays showing particularly good agreement.

Table 29

Supplement	Rate milligrams per sq. ft.	Final Number Mushrooms per sq. ft.			Final Weight oz. per sq. ft.		
		Treat'd	Contr'l	Increase	Treat'd	Contr'l	Increase
Riboflavin	1·6	10	8	25%	6	5	20%
Calcium pantothenate	1·6	12	8	50%	6	4	50%
Phenoxyacetic acid	1·6	32	17	88%	12	10	20%
Stilboestrol	1·6	12	8	50%	6	5	20%
Potassium chlorate (2 trays)	170	2	17	—88%	2	7	—70%

In connection with Experiment 4, groups of six beds were treated with calcium pantothenate and phenoxyacetic acid, 1·6 mg. per sq. ft. Table 30 shows the mean increases in yield over the untreated control beds.

Table 30—Increase due to growth substances

	Number per sq. ft.	s.e.	Oz. per sq. ft.	s.e.
Calcium pantothenate	2·6	± 3·2	1·2	± 1·8
Phenoxyacetic acid	2·2	± 1·9	2·3	± 1·6

No effect due to the treatment was established. There was no effect on the start of cropping.

Tray Experiment No. 6

This experiment was planned to test the effect of peak heating, growth substances, and the use of casing soil without our usual additions of sand and lime.

Messrs. Noble Mushrooms Ltd. kindly arranged to fill 24 trays with horse manure compost and to put twelve of them in one of their houses during peak heating to 120° F. All 24 trays, heated and unheated, were spawned at the same time and thereafter were treated alike, except for the other experimental treatments which were evenly distributed in both groups. The experimental design is shown in Table 31.

Each of the supplements was applied at the rate of 5 mg. in 50 ml. of water per tray of 4 sq. ft. Sand was added at the rate of 1 part in 7 and hydrated lime at 32 lb. per ton of soil.

The casing soil as dug and used in this experiment without sand and lime had pH 7·1—7·5. The pH of other samples has ranged up to 7·9. When freshly mixed with hydrated lime the pH went up to 11·6-12·0. In ten days it fell to about 10 and soon after casing it was down to about 8. It is quite possible that the buffering power conferred by lime is as important as the pH at casing.

Table 31—Number of trays in each group

Supplement	Peak heated		Not peak heated	
	Sand and Lime	Plain soil	Sand and Lime	Plain soil
Calcium pantothenate	2	2	2	2
Sodium phenoxyacetate	2	2	2	2
None	2	2	2	2

Table 32 shows the average days from spawning to the first appearance of pinheads for the main treatments.

The only effect which may be significant is that of calcium pantothenate which gave a later crop on peak heated trays and a slightly earlier one on unheated trays. The difference is not great enough to be conclusive. The yields after 12 weeks picking are shown in Tables 33 and 34.

None of the differences in weight was quite significant, the two most conspicuous being the 19% greater yield with plain soil, and the greater yield from a combination of unheated compost with plain soil. The variation in number per sq. ft. was high and there were no significant differences.

Table 35 shows the average duration of cropping for the main treatments and for the combinations showing differences which might be significant.

Table 32—Interval from spawning to first pinheads

	days
Peak heated	46
Unheated	45
Soil plain	45
Soil with sand and lime	46
No supplement	45
Calcium pantothenate	47
Sodium phenoxyacetate	45
Standard error	± 1

	Peak heated days	Unheated days
No supplement	44	46
Pantothenate	49	44
Phenoxyacetate	45	45
Standard error	± 1·4	

Table 33—Yields after 12 weeks

	mushrooms per sq. ft.	oz. per mushroom	lb. per sq. ft.
Peak heated	20·6	0·68	0·87
Unheated	18·8	0·82	0·96
Soil plain	20·3	0·78	0·99
Soil with sand and lime	18·9	0·71	0·83
No supplement	18·5	0·68	0·79
Ca pantothenate	16·3	0·77	0·78
Sodium phenoxyacetate	17·4	0·80	0·87
Standard error			± 0·11

Table 34—Interaction between soil and peak-heating

	Plain soil lb. per sq. ft.	Sand and Lime lb. per sq. ft.	
Peak heated	0·87	0·87	± s.e. 0·12
Unheated	1·12	0·80	

Table 35—Duration of cropping

	Peak-heated days	Unheated days	s.e	Mean days	s.e.
No supplement	81	74		78	
Pantothenate	74	82	± 4·4	78	± 3
Phenoxyacetate	78	60		69	
Plain soil	75	79		77	
With sand and lime	79	65	± 3·5	72	± 2·5
Mean	77	72	± 2·5		

The cropping period was slightly shorter on unheated trays cased with soil containing sand and lime, on heated trays treated with pantothenate, and on unheated ones treated with phenoxyacetate. When there are no significant main effects interactions such as these on the verge of significance must be viewed with caution and definite conclusions are not justified.

Peak heating may be regarded as a form of insurance to correct faults due to incorrect or uneven fermentation, and it is possible that the compost used in this experiment was a relatively good one, not requiring treatment.

Conclusions

The experiment did not establish any effect attributable to peak heating horse manure ; to the addition of sand and lime to M.R.A. casing soil, or to the application of calcium pantothenate and sodium phenoxyacetate to the beds before casing at the rate of 1·25 mg. per sq. ft.

Some evidence was obtained to suggest that there may be some relation between peak heating and the other treatments applied.

Tray Experiment No 7

This experiment was designed to study the effect of filling trays with compost at successive turns. The saving in material, labour and space which could be achieved by filling earlier than is customary will be obvious. Our practice has been to fill at the 5th turn.

One stack of approximately 1 ton of compost was made in a bay shielded on each side by bales of straw, so that conditions were approximately the same as usual in our experiments. The constituents are given in Table 36.

At each of the 3rd, 4th and 5th turns nine trays were filled, and placed under the bottom shelf in House No. 2, which had been filled with composts of Experiment 5 a few weeks earlier.

Table 36

Straw (6 bales)	540 lb.
Dried blood	55 lb.
Nitrochalk	18 lb.
Potassium sulphate	8 lb.
Ground limestone	2½ lb.
Superphosphate	8½ lb.
Gypsum	26 lb.
Trace elements	

No peak-heating was possible, and all the trays were spawned together four days after the last batch were filled, so that the temperature and other conditions during the spawn run were identical.

At the same time three trays in each group were treated with 50 ml. of 1% solution of beef extract to 4 sq. ft., and three with stilboestrol, 6.4 mg. per 4 sq. ft. tray ; a solution of the stilboestrol was dispersed on sand which was then dried and scattered on the trays.

The intervals between spawning and first picking are summarised in Table 37.

Table 37—Days from spawning to first picking

Supplement	Turns			Mean all turns
	3	4	5	
Beef extract	55	56	56	76
Stilboestrol	71	76	65	71 } ± s.e. 1·1
None	67	76	61	69
			± s.e. 2·0	
Mean, all supplements	64	69	61 ± s.e. 1·1	

The effect of beef extract on all three turns, and the difference between turns in the absence of beef extract are statistically significant.

Very few mushrooms were picked from these trays after the 8th week of cropping. The average numbers of mushrooms produced in 8 weeks are given in Table 38, weights in Table 39, and average sizes in Table 40.

Table 38—Number of mushrooms per tray

Trays filled at turn	None	Supplement Beef extract	Stilboestrol	All supplements mean
3rd	13	29	16	19
4th	17	47	16 } ± s.e. 9	27 } ± s.e. 5·3
5th	18	39	17	25
All turns, mean	16	38	16 ± s.e. 5·3	24

Table 39—lb. per tray (4 sq. ft.)

Trays filled at turn	None	Supplement Beef extract	Stilboestrol	All treatments mean
3rd	1·0	1·1	0·9	1·0
4th	1·2	2·6	1·6 ± s.e. 0·3	1·8 ± s.e.0·2
5th	1·4	2·1	1·6	1·7
All turns, mean	1·2	1·9	1·4 ± s.e. 0·2	1·5

The best group of three trays gave 0·65 lb. per sq. ft.

Table 40—oz. per mushroom

Trays filled at turn	None	Supplement Beef extract	Stilboestrol
3rd	1·2	0·6	1·0
4th	1·1	0·9	1·5
5th	1·2	0·8	1·4

The following results at 8 weeks were statistically significant.

Beef extract increased the number at all turns.

Beef extract increased the weight at the 4th and 5th turns.

With beef extract, but not in its absence, there was a significant difference in numbers and weight between turns.

In unsupplemented compost or with stilboestrol, the time required for fruiting rose from the 3rd to the 4th turn, and then fell again to its lowest value at the 5th turn. These fluctuations were wiped out by beef extract, which apparently provided abundance of some factor needed to start fruiting, and advanced cropping in all cases. This might be due to stimulation of the growth of spawn. When fruiting had started the number of mushrooms produced became important. There was a slight but not significant increase in numbers from the 3rd to the 5th turn, without supplements, and this was accompanied by a corresponding increase in weight. The average size of these mushrooms, over 1 oz. each, was large for shallow trays and this suggests that the crop was being limited by the lack of a stimulus to fruiting, ample food being available for those mushrooms which were formed.

When beef extract was added there was a great increase in the number of mushrooms produced at all turns. A difference also appeared between turns. It seems as though the 4th and 5th turn composts also contained stimulating factors, which could only function if those found in beef extract were present.

The fact that the 4th turn compost produced more and larger mushrooms than the others suggests that it has more nutritive value. This implies synthesis between the 3rd and 4th turns, and some breakdown after the 4th turn. Although most of these results are statistically significant they obviously need confirmation.

Conclusions

Fruiting started soonest on fifth turn compost ; fourth turn compost came into crop last.

Beef extract wiped out this difference and brought all composts into crop 10-20 days earlier.

Beef extract increased the number and weight of mushrooms produced on compost filled at the third, fourth and fifth turns.

Beef extract also brought out differences between trays filled at these stages.

With beef extract the fourth turn compost produced the greatest number and the greatest weight of mushrooms.

Beef extract and fourth turn compost probably supplied substances which stimulate the formation of mushrooms.

Fourth turn compost supplied more food material to support the growth of mushrooms than did third turn compost.

Fifth turn compost was intermediate in respect of both stimulating and food constituents.

Experiment No. 8

The experiment was arranged with the following objects.

1. To assess the progress made with synthetic composts by comparing the latest product with good horse manure, and with a typical proprietary activator.
2. To ascertain whether a mixture of M.R.A. synthetic compost and horse manure was better than either or both of them individually.
3. To ascertain whether the process of fermentation with horse manure had any effect which could not be obtained merely by its presence in the finished compost.

Object No. 1 was not achieved in respect of horse manure, but the other objects were, with some limitations.

Six sets of experimental composts were laid down.

A. Horse manure "A"— stacked 3rd and 4th June.

B. Horse manure " B "—stacked 3rd and 4th June.
These were separate parts of a truck of London transport stable manure. The manure was rather short and it is almost certain that we under-estimated the amount of straw which should be added to it. 1 bale (approximately 90 lb.) of straw was added to each $\frac{1}{2}$ ton of manure.

C. M.R.A. Compost—stacked 31st May and 1st June.
315 lb. wheat straw composted with :—

Added in layers at first stacking	**Added at the 4th turn**
42 lb. dried blood.	4 lb. superphosphate.
2 lb. sulphate of potash.	10 lb. gypsum
7 lb. ground chalk.	trace elements.
5 lb. gypsum.	

D. Proprietary Compost—stacked 31st May and 1st June.
Wheat straw composted with the Proprietary Compost Activator at the rate advised by the makers, 14 lb. to 315 lb. of straw.

E. Horse manure and M.R.A. Compost mixed early.
A stack of horse manure 'A' started on 3rd June was mixed on 15th June with a stack of M.R.A. compost which had been started on 31st May and turned once on 8th June. The mixture was divided into two stacks which were then treated separately.

F. Horse manure "A" and M.R.A. Compost mixed at filling.
One stack of horse manure "A" and one of M.R.A. synthetic compost were treated normally until the day of filling, when they were mixed to give compost equivalent to two stacks.

Four stacks were made with each of these six treatments; for each of the mixing treatments two M.R.A. and two horse manure stacks were started, giving four mixed stacks for filling the beds. Three beds of 10 sq. ft. were filled from each stack, one each on the top, middle and bottom shelves of the house. The 24 stacks were arranged in two rows, 12 along the East and 12 along the West side of the composting shed. At the time of the experiment the straw bales forming the West wall had been replaced by iron sheets, and the stacks on this side fermented at a lower temperature than those on the East side, where the straw bale wall assisted retention of heat. This introduced an additional difference in treatment, uncontrolled but measurable, into the experiment.

Table 41 shows the average maximum temperatures for the various treatments, sides of the composting shed, and turns.

Table 41—Maximum stack temperatures

	East	West side of shed
Horse A	119° F.	115° F. (mean of all turns)
Horse B	135° F.	111° F.
Proprietary compost	133° F.	115° F. ± s.e. 4·5 deg. F.
M.R.A.	135° F.	122° F.
M.R.A. & Horse mixed "E"	142° F.	128° F.

The differences between treatments and sides of the composting shed were significant.

It was noted at filling that inkcaps grew freely on all the M.R.A. stacks but none grew on those made with the Proprietary compost. The Proprietary compost was still very light and open in texture but the straw broke easily. A note was also made that stack No. 18 was rather less composted than the other M.R.A. stacks and might have taken another turn. This is particularly interesting since No. 18 gave

one of the best yields obtained, and tends to support the results of a tray experiment which favoured earlier filling.

The crops as a whole were very unsatisfactory. A few days after spawning brown plaster mould developed on the composts mixed at filling and spread rapidly over the whole house. The beds were limed and dried off and then cased, but the attack might be expected to reduce the yield.

The yields from Horse Manure Composts A and B and the proprietary compost were so low, some beds failing completely, that they have not been included in the analysis of variance and table of yields, Table 42. This does not affect the validity of comparisons between M.R.A. Compost and mixtures containing horse manure.

Table 42—Summary of yields

	Composts				Stack blocks		
	M.R.A.	Mixed E	Mixed F	s.e.	East	West	s.e.
Days to first pinheads	56	51	38	±10	48	49	± 8
No. per bed 12 weeks (10 sq. ft.)	67	85	89	±42	74	87	±20
lb. per bed 12 weeks	5·2	6·2	5·9	± 1·9	5·6	6·0	1·5
Average size, oz. per mushroom 0-12 weeks	1·2	1·2	1·1		1·2	1·1	
Average duration of picking, days	80	77	83	±11	87	73	9

The best group of three beds of M.R.A. compost gave 0·8 lbs. per sq. ft. and of M.R.A. mixed with horse manure 0.85 lbs. per sq. ft.

There are some quite large differences in the intervals from spawning to first picking; 'F' composts (mixed at filling) started to fruit first.

'F' composts also produced most mushrooms and slightly the greatest weight during the first 4 weeks picking. During the next 4 weeks the E composts (mixed early) caught up 'F,' and the M.R.A. gained a little. During the last 4 weeks there was no difference in number or yield. The quick start and larger number of small early mushrooms suggest that the 'F' composts are richer in growth substances than the "E" and plain M.R.A. composts.

Analysis did not show any abnormality to account for the failure of the horse manure composts. This and the yield obtained by mixing horse manure and M.R.A. composts suggest that the fault lay in the physical rather than chemical properties ; the horse manure appeared to be over-composted.

Conclusions

The difference in final yield between M.R.A. synthetic compost and mixtures of M.R.A. and horse manure composts mixed early in composting or at filling was not significant.

There was no indication that the presence of horse manure during composting has any particular beneficial effect.

The compost mixed at filling came into crop first.

The horse manure produced poor crops, probably because of over composting.

The Proprietary compost was very low in nitrogen and produced a poor crop.

Test of Peak-heated M.R.A. Compost by Messrs. Noble Mushrooms Ltd.

During the period under review experimental conditions have prevented an effective peak-heat being obtained in the M.R.A. test houses.

When composts for Experiment No. 8 were made six boxes of normal depth (7 inches) were filled with M.R.A. synthetic compost, three from each of two stacks, Nos. 17 and 18, and passed to Messrs. Noble Mushrooms Ltd., whom we have to thank for their subsequent management of the boxes, and for the following crop records.

Two boxes from each stack were peak-heated (boxes 1 and 2 to 113° F., 4 and 5 to 120° F.) and the third was not.

The yields obtained are shown in Table 43. The average after 12 weeks picking was 3·0 lb. per sq. ft. from the 4 peak-heated boxes.

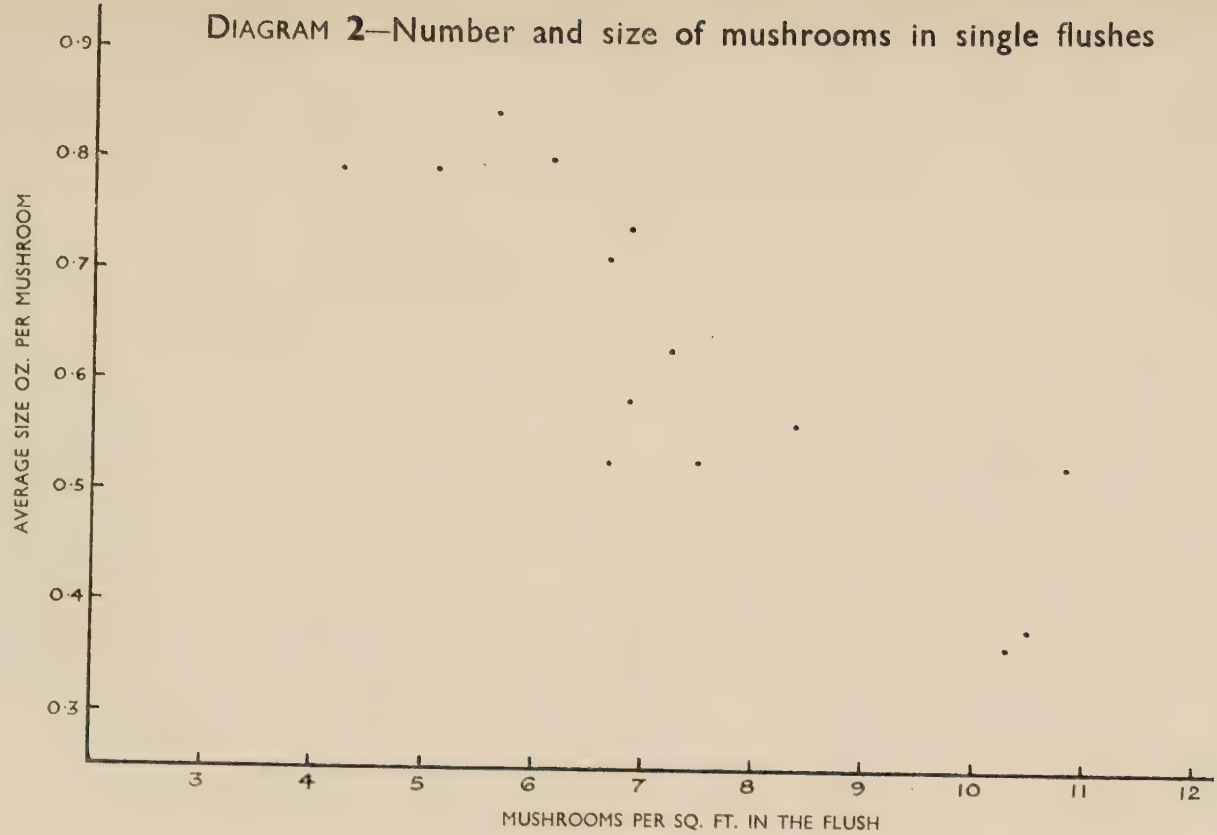
Table 43 —Yields from boxes of M.R.A. compost

	Stack 17			Stack 18		
	Box 1	2	3	4	5	6
	peak-heated		(unheated)	peak-heated		(unheated)
4 weeks	1·0	1·0	0·7	1·4	1·5	0·6 lb. per sq. ft.
8 ,,	1·4	1·7	1·0	2·6	2·8	1·1 ,,
12 ,,	2·5	3·0	1·0	3·1	3·6	1·3 ,,
16 ,,		3·2		3·4	3·8	,,
18 ,,					4·0	,,

Relation between Number and Size of Mushrooms

In several experiments where the number of mushrooms produced per square foot has varied owing to non-nutritional causes, an inverse relation between number and size of the mushrooms has been observed.

DIAGRAM 2—Number and size of mushrooms in single flushes



In Experiment 1 the beds spawned at 8 inch intervals at first gave more but smaller mushrooms than the 12 inch spawned beds, and when the latter began to produce more mushrooms they in turn were smaller. A similar effect was produced in Experiment 5, when spraying the compost before casing reduced the number and increased the average size of the mushrooms.

A similar relation has been found on comparing single flushes on groups of similar beds. Diagram 2 shows the relation between number and size for deep beds of plain compost spawned at 12 inch intervals in Experiment 1. All flushes from second to sixth on the three beds receiving this treatment are included. Other groups of beds in the same experiment gave similar diagrams, but on some composts the flushes vary so much that no relationship can be established.

Additional indirect evidence in support of this relation between number and size of mushrooms is provided by the analyses of variance. In all experiments the standard error expressed as a percentage of the mean is much greater for the number of mushrooms than for the weight per sq. ft. Thus the wide fluctuation in the numbers of mushrooms produced is represented by a high standard error. This fluctuation is balanced by opposite variation in size, tending to make the total weight more nearly constant on similarly treated beds, and so reducing its standard error. Observations on this subject will be continued.

Growth Rate of Mushrooms

During the course of Experiment 1 the growth in diameter of some mushrooms was measured daily by calipers. It was found that between 20 and 55 mm. diameter with the veil intact the average rate of increase in 24 hours was 30% of the diameter of the cap (see Diagram 3) ; the temperature range was 55-60° F. When the veil opens and the cap flattens there is an even more rapid expansion. While these measurements were being made mushrooms covering the same range of sizes were weighed and measured individually after picking and cutting off the sumps as usual. The results are shown in Diagram 4. From these two diagrams it may be estimated that a mushroom can approximately double its weight in 24 hours. Most of these measurements were made on mushrooms growing singly, for the sake of convenience. It is quite probable that mushrooms clustered on a single stump would grow more slowly; and other factors, such as compost, soil, and watering may also affect the size and growth rate.

Some evidence has been collected proving that mushrooms continue to increase in weight after the veil has opened, contrary to the belief of some growers.

In Experiment 2 over 1,000 mushrooms from 36 beds filled with 12 composts, were weighed and measured individually. On comparing the heaviest closed and the heaviest open mushroom from each compost there is an average difference of 18 grams ($\pm$ s.e. 4·5) in favour of the closed mushrooms. If growth stopped when the veil opened the difference would probably be insignificant. Also, when the heaviest mushrooms just open were compared with the heaviest flat ones on each compost the latter were on the average 21 grams ($\pm$ s.e. 10) heavier.

DIAGRAM 3—Rate of growth of mushroom cap before the veil opens

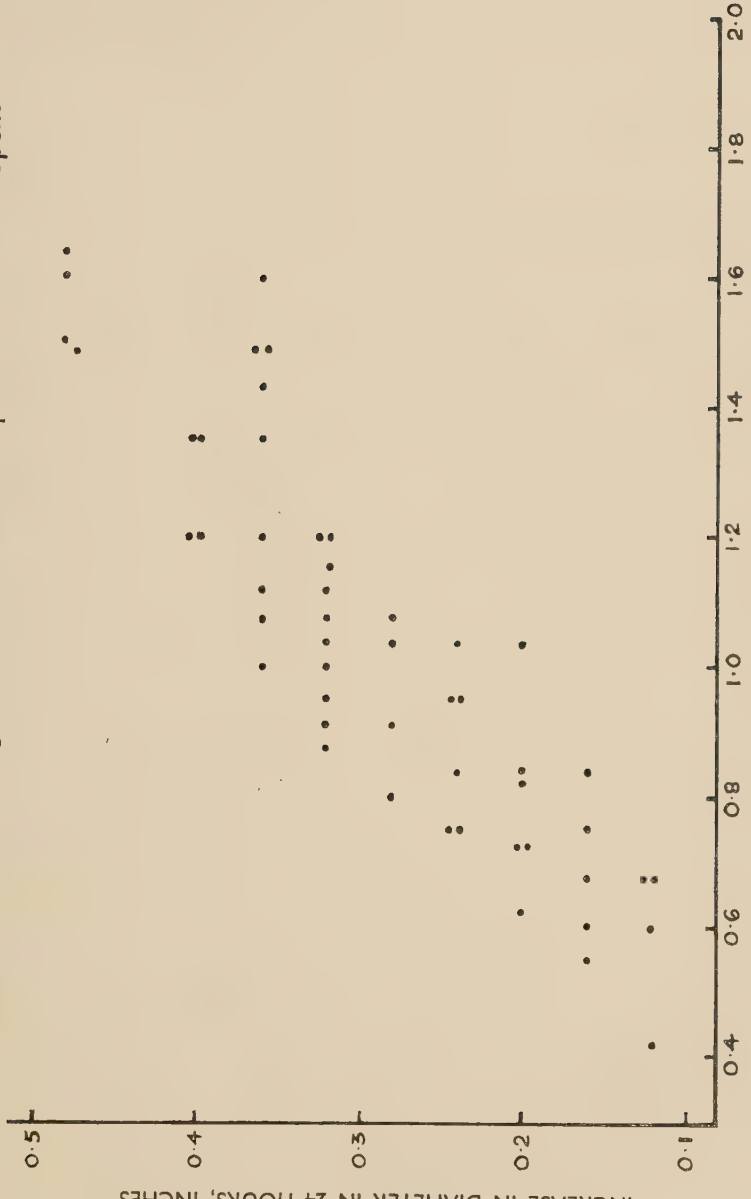
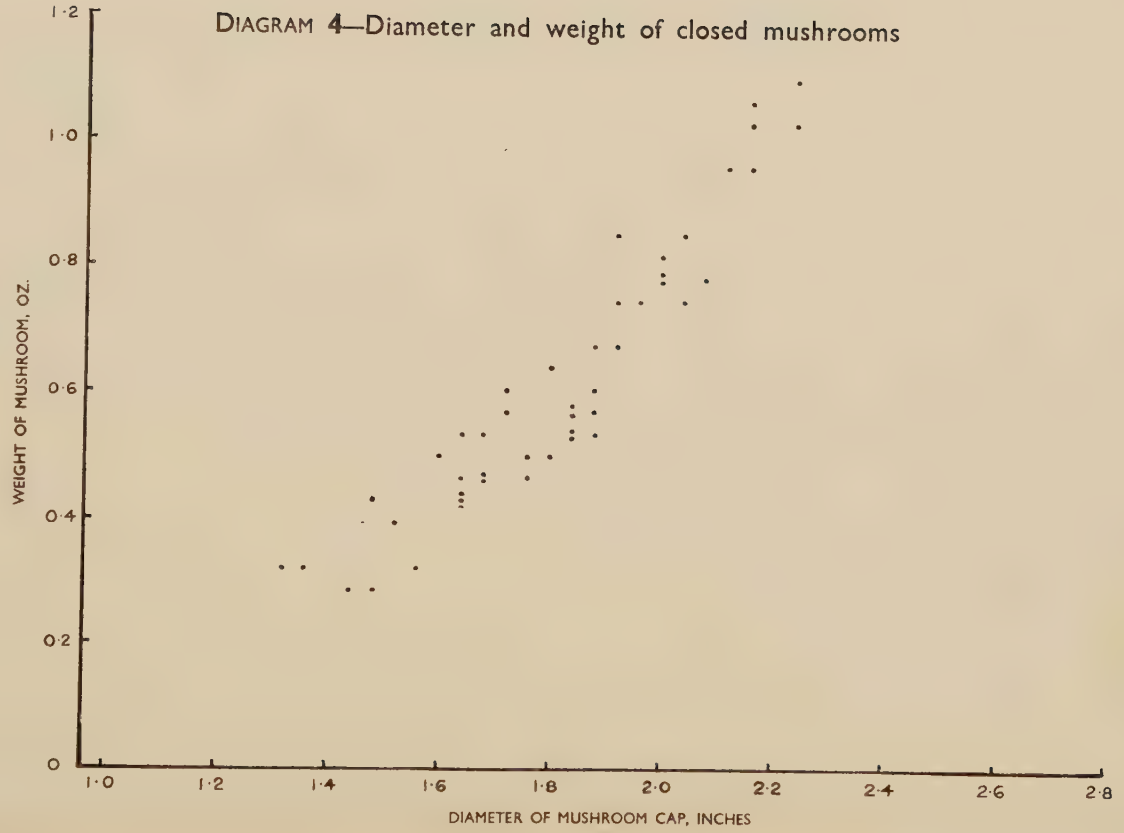


DIAGRAM 4—Diameter and weight of closed mushrooms



Finally nine pairs of mushrooms were selected, and one of each pair, chosen at random, was picked after the veil opened, the other mushroom being picked 24 hours later. The average difference in weight in favour of the mushrooms picked later was 4·9 grams (± s.e. 1·2). This significant difference is direct evidence for the continuation of growth after the veil had opened.

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CHEMISTRY DEPARTMENT — S. Burrows

The principal work undertaken during the period under review has been the analysis of composts at various stages during their preparation and during cropping in order to investigate the changes taking place. Little work has so far been done on the organic matter of composts owing to the difficulty of characterising the various fractions present, although this aspect is probably of considerable importance. The analysis of composts has involved a certain amount of preliminary work on sampling methods and adaptation of analytical methods and physical tests.

A number of investigations of limited scope have also been undertaken in the chemistry department and these will be briefly summarised.

Sampling

The methods of sampling adopted have proved in general to be satisfactory. Their accuracy is now being more fully tested on greater numbers of samples. Sampling is usually done at three main stages :—

1. At the commencement of composting.
2. When filling into the beds for cropping.
3. When emptying exhausted compost from the beds.

Some samples are also taken at intermediate stages for special purposes.

Stage 1 : This is the most difficult stage for sampling and an ideal method has not yet been found. At present it is left until the first turn when straw and activators have been well mixed and sampling can be done in a similar manner to stage 2 except that the straw is chaffed before quartering.

Stage 2 : After the compost has been mixed ready for filling the beds, large forkfuls are removed, mixed, and quartered on a concrete floor with a sharp spade until about 4 lb. remains.

Stage 3 : The casing soil is carefully scraped from the top of the bed, taking a little of the compost also so that the sample is quite free from soil. With a trowel roughly cylindrical sections are cut from various parts of the bed right down to the bed-boards. If samples are required during cropping this is done with a sharp annular boring instrument 1-1½″ diameter inserted vertically in the bed. The core of compost and soil so obtained is carefully pushed out and soil separated from compost.

At each stage the final sample is well mixed and quartered, half being taken and used without drying for the determination of total nitrogen, pH and size analysis and the other half dried overnight at 90-100° C. and milled to pass the 1 mm. sieve, weighing before and after drying to obtain the moisture content.

The following tests and determinations are usually performed :—

Stage 1 : Total nitrogen, total ash, acid insoluble ash.

Stage 2 : Bulk density, size analysis, moisture, pH, total ash, acid insoluble ash, total nitrogen, phosphorus, potassium, calcium, and magnesium.

Stage 3 : As stage 2 with the addition of calcium oxalate.

Protein nitrogen and ammonia nitrogen have also been determined on some samples.

These determinations have been undertaken with the following objects :—

(*a*) To check the proportion of nitrogen, phosphorus, potassium and calcium present and to observe changes in dry matter and total nitrogen during composting.

(*b*) To investigate the relationships between mushroom yields and composition and physical properties of compost at filling.

(*c*) To calculate absolute changes during cropping and find the relationship between these and crop yields or other variables.

Since compost organic matter is lost (mainly as carbon dioxide and water) during composting and cropping, the changes mentioned in (*a*) and (*c*) cannot be obtained directly from the observed percentages present and an estimate of the dry matter lost must first be made. This may be done directly by weighing the whole compost in a bed, or more conveniently by calculation assuming that the total amount of acid insoluble ash remains constant. A further recalculation is also necessary when comparing composts of different densities or composts which have been filled to different depths in the cropping beds. Cropping is a surface phenomenon and yields are expressed in lb. or oz. per sq. ft. so that changes in composition should also be expressed in this way for comparison with yields. This can be done from a knowledge of the bulk density, moisture and depth of compost in the bed. If densities are uniform, depth of compost only is required.

Methods of Analysis

The following is a brief outline of the methods employed :—

Moisture	Air oven at 105° C.
pH	Glass electrode.
Total ash	Commence at 300° C. Finish at 500° C.
Acid insoluble ash	Ash at 500° C. after extracting total ash with hot 0·5N hydrochloric acid.
Total Nitrogen	Duplicate 20g. samples of fresh compost digested using selenium catalyst, continued for 45 minutes after the digest is clear. Precautions for including nitrates are taken.
Phosphorus	Dickman and Bray's Method (1940) after ashing with magnesium acetate (Piper, 1947).
Potash	Turbidimetric cobaltinitrite method adapted from Tinsley's (1949) method.
Calcium	Permanganate titration of precipitated calcium oxalate.
Magnesium	Titan Yellow Method (Stross, 1942) after removal of aluminium and phosphates.
Oxalate	Absorptiometric method developed in this laboratory (Burrows, 1949a), using the fading effect of oxalates on the green colour of the compound of iron and 7-iodo-8-hydroxy-quinoline-5-sulphonic acid.
Bulk density	By filling with compost and weighing an open drum of known volume. Compost is packed into the drum using the same pressure as would be

exerted in filling a mushroom bed. The mean of duplicate determinations is fairly reproducible for a single operator. Comparison between the operator and those filling the mushroom beds is necessary.

Size Analysis — Empirical method for comparing the proportion of colloids and fine material in composts. This method is not yet in its final form. It involves the addition of a volume of water to give a constant dry matter to water ratio, expressing the liquid under strictly defined conditions, sedimentation and measurement of sediment height and light absorption of the supernatant liquid.

RESULTS

pH During Composting

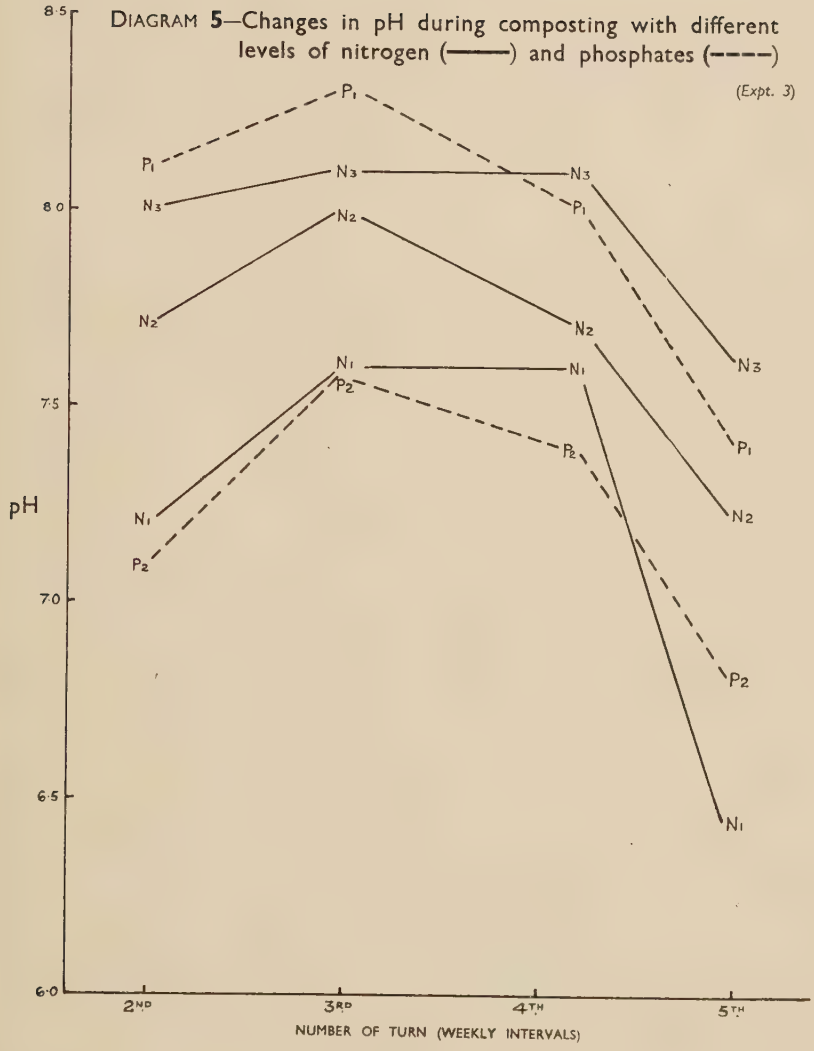
pH changes during the preparation of synthetic composts have followed the general trend for horse manure composts in that a maximum was reached at the third or fourth turn followed by a drop which was somewhat more rapid than the initial rise. The maximum pH attained depended mainly on the amount of nitrogen in the original mixture (higher nitrogen gave higher maximum pH) and on the type of nitrogen compounds used (inorganic materials gave lower pH). Other factors such as temperatures during composting, addition of trace elements and other supplements also probably affected the maximum pH reached. Addition of superphosphate before or after composting lowered the pH to an extent depending upon the amount added. The effect of different levels of nitrogen and phosphorus upon pH changes during composting is shown in Diagram 5. Changes in pH during cropping may depend on a variety of factors such as rapidity of spawn growth, buffer capacity of the compost and good or bad aeration in the compost. The buffer capacity may be of importance in controlling the duration of flushes. Some evidence for this was obtained in Experiment 1 where the limestone treated compost had a much higher buffer capacity than the gypsum treated and untreated composts as shown by the electrometric titration curves (Diagram 6). At pH 6·0, the approximate pH of compost during cropping, the fall in pH produced by the same amount of acid was about three times greater for the gypsum treated than for the limestone treated compost. The duration of flushes on the limestone compost was greater than that on the other composts.

Dry Matter Changes During Composting

Only a few ash determinations before composting are available so that quantitative data are lacking but a comparison of mean ash figures for each treatment at filling gives an indication of the relative amount of dry matter lost by the composts within each series. No large differences were seen in any of the Experiments 2, 3 or 5, showing that the main treatments (4 levels of nitrogen, 2 levels of phosphorus, trace elements, organic and inorganic forms of nitrogen) had only small effects upon the rate of loss of organic matter. This is surprising in view of the obviously greater shrinkage of stacks composted with organic nitrogen

DIAGRAM **5**—Changes in pH during composting with different levels of nitrogen (——) and phosphates (– – – –)

(Expt. 3)



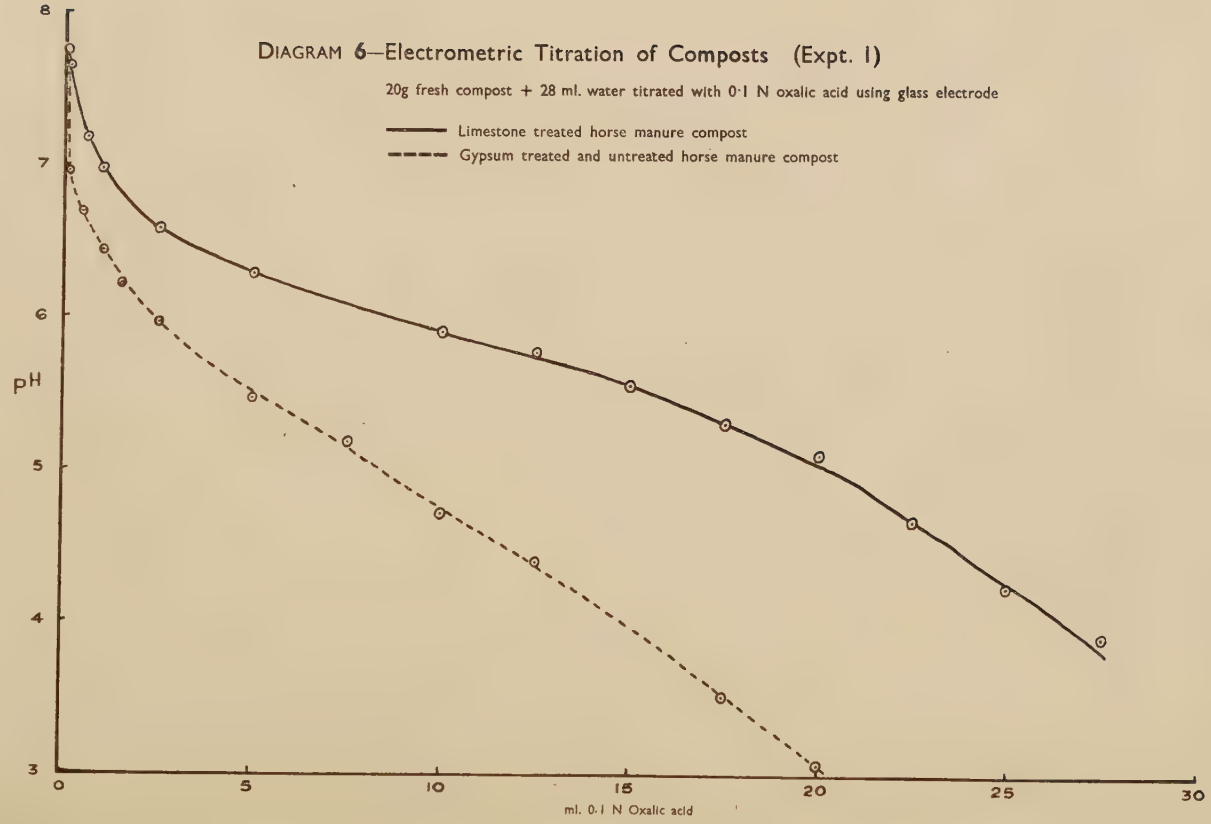


DIAGRAM 6—Electrometric Titration of Composts (Expt. 1)
20g fresh compost + 28 ml. water titrated with 0·1 N oxalic acid using glass electrode
Limestone treated horse manure compost
Gypsum treated and untreated horse manure compost
pH
8
7
6
5
4
3
0
5
10
15
20
25
30
ml. 0·1 N Oxalic acid

and also higher levels of nitrogen. In these stacks the straw was more easily broken, indicating a greater breakdown of cellulose. The discrepancy is at least partly explained by the greater density of these composts.

Nitrogen Changes During Composting

Table 44 shows the estimated changes in total nitrogen and carbon/nitrogen ratio during Experiment 3 in which three levels of nitrogen as dried blood were used. The figures are the means of four separate composts (duplicates with two levels of phosphorus each).

Table 44

N level	At Start		At Filling				
	Total N as % of original dry matter	C/N Ratio	Total N as % of dry matter at filling	Estimated dry matter as % of original	Total N as % of original dry matter	Change in total N % of original dry matter	C/N Ratio
N_1	1·1	43	2·08	65	1·35	+0·25	20
N_2	2·0	24	2·54	65	1·65	—0·35	16
N_3	2·9	16	2·97	65	1·93	—1·0	14

Total nitrogen was determined at filling and the nitrogen originally present was estimated from the nitrogen content of the straw and of the dried blood added. The loss of dry matter during composting was obtained by comparing the total ash at filling with the estimated ash content of the original compost. Carbon figures for the carbon/nitrogen ratios were found by dividing losses on ignition by 1·8.

There was an increased loss of nitrogen with increasing nitrogen level (Diagram 7) but this was not accompanied by any increase in the loss of organic matter. As a result the gaps between the respective carbon/nitrogen ratios closed up during composting and this is shown graphically in Diagram 8. The apparent gain in nitrogen in the low nitrogen level composts may be due to approximations in the recalculations although Hutchinson and Richards (1921) found a similar effect in composts containing less than 2% of nitrogen.

Dry Matter and Oxalate Changes During Cropping

In Experiment 1 dry matter losses during cropping have been calculated from total ash determinations after 12 weeks and 20 weeks cropping respectively. Losses calculated from total ash figures are usually two or three per cent. lower than those obtained from acid insoluble ash figures, probably owing to assimilation of soluble mineral matter and its transportation to the casing soil mycelium and the fruit bodies. Table 45 gives the mean dry matter loss figures for the three compost treatments in this experiment (12 beds for each treatment).

DIAGRAM **7**—Effect of Nitrogen Level on Loss of Nitrogen During Composting.

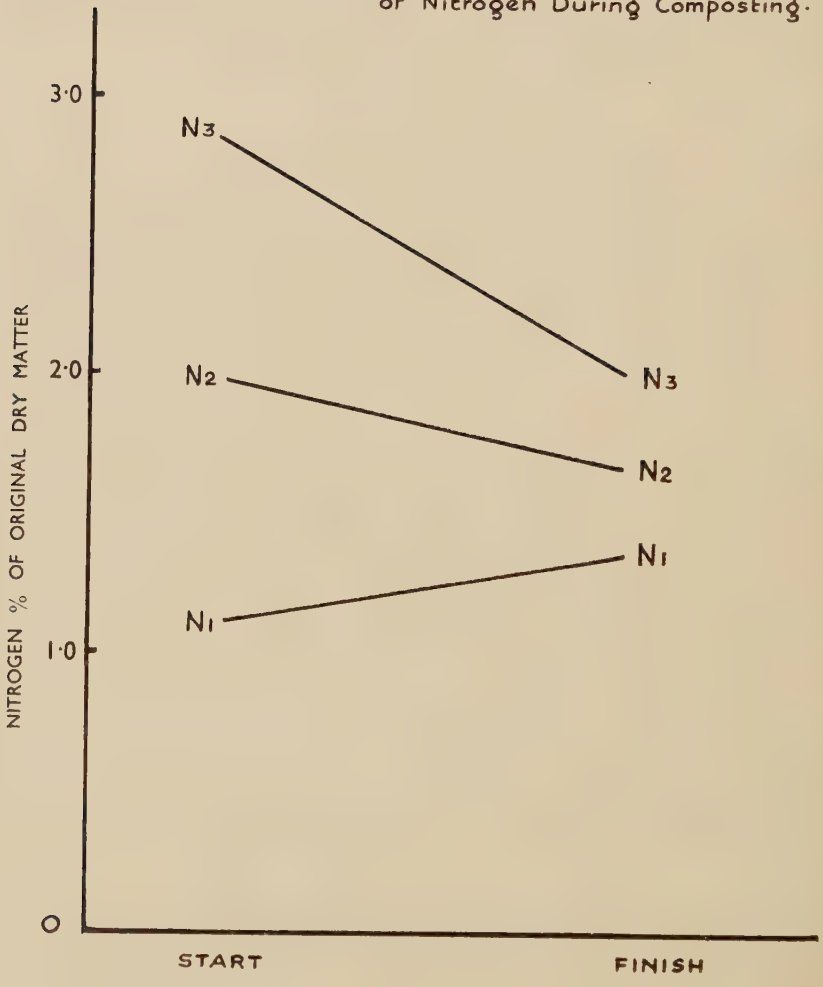
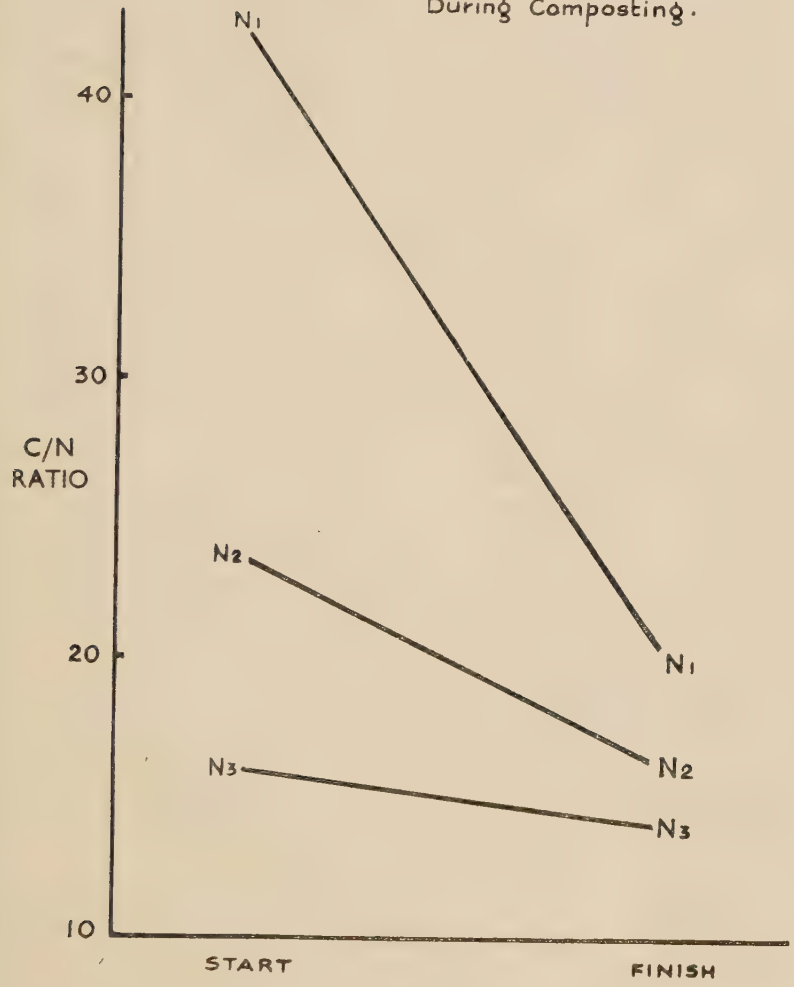


DIAGRAM 8—Change of C/N Ratio During Composting.



Dry matter is lost at the mean rate of 1·5% per week during the period from spawning to the 20th week whereas the rate is only about 0·5% per week during the last eight weeks of cropping. Since the loss of dry matter due to the respiration of mushroom mycelium must be slow during the first few weeks after spawning the maximum rate of dry matter loss may be greater than 1·5% per week. This falling off of respiration rate was confirmed by some respiration experiments in which two mushrooms were grown at different times on compost in an enclosed jar. Moist air was led in and the carbon dioxide in the outgoing air was determined.

Table 45

Compost Treatment	Dry matter loss (% d.m. at filling)		Difference
	12 weeks cropping 20 wks. from spawning	20 weeks cropping 28 wks. from spawning	
Limestone	28·6	32·8	4·2
Gypsum	27·1	32·1	5·0
Untreated	31·5	32·7	1·2
Overall Mean	29·1	32·5	3·5

The mean rates of carbon dioxide production at various temperatures are given in Table 46.

Table 46—Carbon dioxide produced by fully grown mushrooms

Weight of mushroom when fully grown		29g.	46g.
mg. carbon dioxide/hr.	20° C.	—	46·2
	27° C.	50·8	78
mg. carbon dioxide/hr./g. mushroom weight at	27° C.	1·75	1·7

Carbon dioxide produced by compost and soil after mushrooms were removed

mg. carbon dioxide/hr.	15° C.	5·0	—
	20° C.	12·2	11·0
	27° C.	25·5	18·5

From these figures it was calculated that during the four months the compost was in the jar the loss of dry matter due to carbon dioxide formation could not be greater than 55 g. Taking 20 g. as the outside figure for loss of dry matter in the mushrooms and stumps removed and in material transferred to the soil, the total loss is 75 gs. compared with an actual loss (by weighing the compost) of 100 gs. A probable explanation of this discrepancy is that carbon dioxide production was greater between spawning and the formation of the first mushroom (a period of 8 weeks) than when the carbon dioxide measurements were actually

made. This higher rate of respiration may be due to a greater activity of the micro-organisms in the compost during the early stages of spawn growth or to a greater respiration rate of the mushroom spawn itself when it first invades the compost, or both these factors may be operating. It is well known that a rapid spawn run is often accompanied by a rise in temperature of the compost indicating a high respiration rate. It is thus possible that carbon dioxide and water are being formed at this stage more rapidly than at any other time and since dry matter is being lost it may be that under certain conditions the percentage moisture content of the compost increases, thus cutting down the aeration. If the compost is a little too moist or a little too tightly packed aeration will be diminished at a time when carbon dioxide is being produced rapidly and a check in mycelial growth may ensue. This critical stage would pass as soon as mycelium runs into the soil, withdrawing and transpiring moisture.

In support of this theory, Pizer (1937) found during beaker experiments with good and bad casing soils that, when no mycelium or fruit bodies formed in the soil, drops of liquid collected at the bottom of the compost in the beakers and degeneration of the spawn occurred. The Americans believe that more air is required during cropping than during the initial spawn run (Rettew, 1948), but the above results suggest that the period of maximum respiration and therefore of maximum oxygen requirements is during the first weeks or so of cropping when the spawn has just penetrated throughout the compost. It is probable however, that mushrooms are more sensitive to carbon dioxide than is spawn (Lambert, 1933), so that more ventilation is, in fact, necessary during cropping.

Under certain conditions mushroom mycelium produces calcium oxalate and the amount formed appears to depend on a number of factors. In Experiment 1 where deep and shallow beds and 8″ and 12″ spawn intervals were used the mean oxalate percentages found, based on the original dry matter in the bed, are given in Table 47.

Table 47

Treatment	Dry matter lost %	Oxalate		
		% calcium oxalate	Standard error of the mean	Significance of oxalate differences
Limestone treated	32·8	1·83	± ·05	P<·01
Gypsum treated	32·1	1·40		
Untreated	32·7	1·57		
Deep beds	31·8	1·69	± ·04	P<·01
Shallow beds	33·2	1·52		
8″ spawn interval	33·8	1·52	± ·04	P<·01
12″ ,, ,,	31·2	1·69		

In two series of synthetic composts the oxalate percentages were generally much lower (0·5% and less) although a few beds had over 1%. No correlation of oxalate with yields exists although there appears to be an inverse relation between dry matter loss and oxalate content which is less marked in the synthetic composts than in the horse manure, and in this latter case the correlation is significant at the 5% level for the beds containing limestone treated and untreated composts but not gypsum treated compost (Table 48).

Table 48—Correlation between dry matter loss and oxalate formation

Compost	Correlation Coefficient (r)	n	P
Limestone	— ·621	10	< ·05
Gypsum	— ·374	10	> ·1
Untreated	— ·667	10	< ·02

These results may be explained merely by differences in aeration producing variations in dry matter loss and opposite variations in oxalate production, good aeration making for high dry matter losses and low oxalate production and vice versa. This would explain the lower oxalate production on the more aerobic synthetic composts but does not explain the lower figures for the 8″ spawn interval beds in Experiment 1. Here we should expect more rapid spawn growth, greater oxygen requirement and therefore limiting aeration conditions and more oxalate production.

Treschow (1944) found that the mushroom can use calcium oxalate as a source of carbon so it may be that oxalate is only formed during periods of limiting aeration or plentiful food supply and is reassimilated when aeration is greater or food supply is less readily available. This might explain the significantly lower oxalate values on shallow beds and 8″ spawn interval beds in Table 47. Under these conditions the period of limiting aeration occurs earlier and readily available food material is used up earlier than in the deep beds and 12″ spawn interval beds leaving a longer period for reassimilation of oxalate.

Moisture Losses During Cropping

The usual technique of watering during cropping consists in uniformly spraying the surface of the beds at frequent intervals, taking care that no water trickles through to the compost beneath. Changes in water content of the compost during mycelial growth and cropping will therefore have superimposed upon them any changes due to external conditions such as humidity, temperature and watering. If the soil dries out unevenly over the house, watering may also be varied to restore uniformity in the soil moisture. For this reason the results of determination of moisture losses from compost may be difficult to interpret.

Water losses have been calculated for the individual treatments (mean of three beds) for three composting experiments, using dry matter

Table 49

Experiment 1				Experiment 3				Experiment 5			
Treatment	Original water lb./sq.ft.	Lost water lb./sq.ft.	Yield lb./sq. ft.	Treatment	Original water lb./sq.ft.	Lost water lb./sq.ft.	Yield lb./sq. ft.	Treatment	Original water lb./sq.ft.	Lost water lb./sq.ft.	Yield lb./sq. ft.
1D8	21	15·8	1·75	N_1P_2	15·1	6·9	0·61	I—	13·9	7·4	1·10
1D12	21	13·7	2·00	N_2P_1	15·4	10·1	1·37	I—	14·0	7·6	0·37
1S8	14	10·7	1·55	N_2P_1+P	14·3	8·5	0·88	IB	12·5	5·8	1·08
1S12	14	9·2	1·40	N_2P_2	13·8	8·4	0·63	IB	12·5	6·3	1·33
2D8	22	15·6	2·10	N_3P_1	15·9	10·5	1·40	IC	12·5	6·6	1·36
2D12	22	15·4	2·05	N_3P_1+P	13·5	8·3	1·11	IC	13·4	7·7	0·83
2S8	15	10·7	1·50	N_3P_1+P	14·5	9·4	1·03	O—	9·8	6·9	1·79
2S12	15	10·8	1·60					O—	12·9	7·6	1·21
3D8	20	12·3	1·75					OB	12·2	6·7	2·10
3D12	20	16·2	1·75					OB	11·3	7·8	0·90
3S8	13	10·0	1·30					OC	11·0	7·8	2·04
3S12	13	9·5	1·30					OC	13·0	8·4	1·48

Explanation of code letters and numbers

1 = Limestone treated
2 = Gypsum treated
3 = Untreated
D = Deep beds
S = Shallow beds
8 = 8″ spawn interval
12 = 12″ spawn interval

$N_1N_2N_3$ = Low, middle and high nitrogen levels
P_1P_2 = Low and high phosphorus levels
+P = Superphosphate added at filling

I = Nitrochalk-dried blood ratio of 3 to 1
O = Nitrochalk-dried blood ratio of 1 to 3
— = No supplement
B = Beet tailings added
C = Castor Bean Meal added

losses calculated as indicated previously. Metabolic water, formed by the breakdown of compost organic matter, was added to these. Since the hydrogen contents of carbohydrates, lignins and proteins all lie between 5% and 7% the water formed will be about 50% of the organic matter completely oxidised, assuming that the cell substance and metabolic products are not richer in hydrogen. Thus an approximate figure for the metabolic water was obtained by halving the dry matter losses. Total moisture losses so obtained, expressed as a percentage of the dry matter present at filling, were converted to lb./sq. ft. of bed area to test for correlation with yields.

In Table 49 the mean crop yield, original water and water lost per square foot are given for each treatment in the composting experiments 1, 3 and 5.

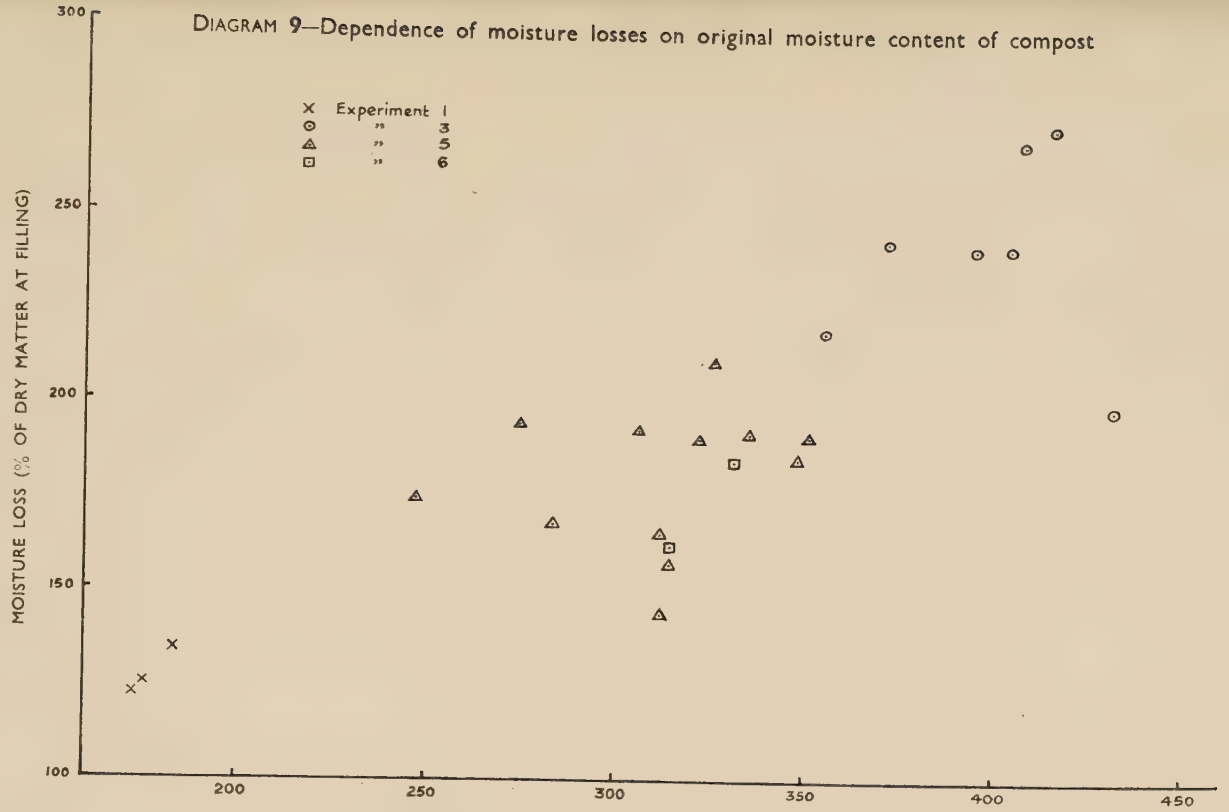
When the water lost was plotted against the yield the points obtained fell into three groups corresponding to the three experiments. Taking each of these groups separately, Experiment 1 gave a steep regression line and the correlation was just significant (P between ·02 and ·05). This correlation, however, must be very strongly influenced by the correlations between yield and depth and between water loss and depth so that if these extraneous effects were removed it is doubtful if the figures would show any relationship between water loss and yield. In Experiments 3 and 5 there are only small variations in compost depth and density and no significant correlation was found to exist between water loss and yield.

Taking Experiments 3, 5 and 6 together, there was a highly significant correlation between the percentage water lost and the original percentage of water present in each compost. These figures are plotted in Diagram 9 (coefficient, $r = +0{\cdot}733$; $n = 19$; $P < {\cdot}01$). Experiment 1 was not included since twelve beds were used for each of the three composts whereas in the other experiments only three beds were used for each compost. Table 50 gives the mean figures for the separate treatments in Experiment 1. The bed treatments (8″ and 12″ spawn

Table 50—Water Losses : Experiment 1

Treatment	% of d.m. at filling	
	Original water	Water loss
Limestone	176	125
Gypsum	173	122
Untreated	184	134
8″ spawning	178	128
12″ spawning	178	126
Deep	178	125
Shallow	178	130

DIAGRAM 9—Dependence of moisture losses on original moisture content of compost



Footnote—In Expt. 6 only two composts were analysed at the end of cropping

interval, deep and shallow beds) showed only small variation in water losses although there is a suggestion of a slightly higher percentage loss from shallow beds than from deep beds.

The moisture in the compost at the end of cropping was still high (between 50% and 60% in this experiment), so that we should have expected a similar amount to evaporate from both deep and shallow beds giving a much higher percentage loss from shallow beds since they were only $\frac{2}{3}$ of the depth of the deep beds. The fact that there was a difference of only a few per cent. suggests that some other factor apart from simple evaporation is operating.

Taking the three different composts in this experiment it can be seen that the percentages of water lost and water present may be correlated within themselves although there is a quantitive discrepancy between these figures and those for the other experiments. Since the physical characteristics of the horse manure compost used in Experiment 1 and the synthetic composts of the other experiments were very different this discrepancy is not surprising.

The following conclusions may therefore be drawn.

1. There is no correlation between water losses and yields.
2. There is a highly significant correlation between losses and original water contents.

Nitrogen Changes During Cropping

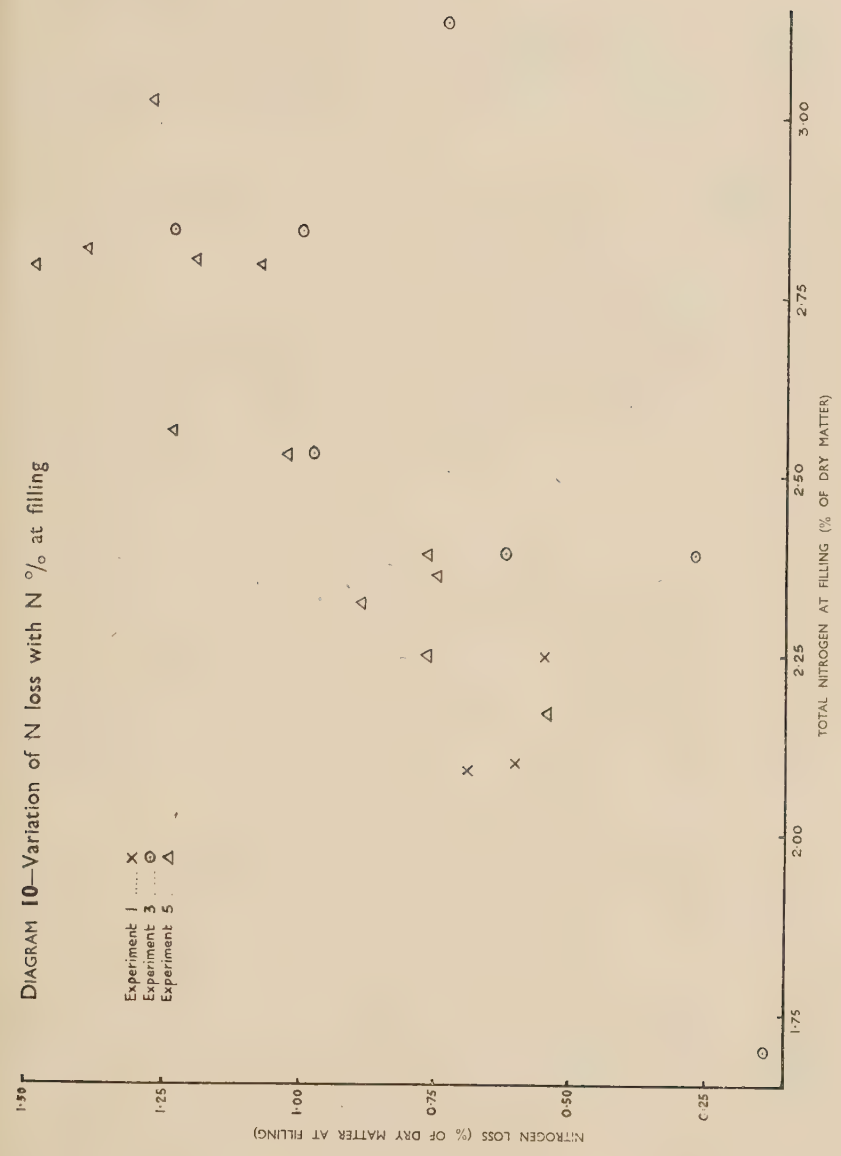
The losses of nitrogen from the composts in Experiments 1, 3 and 5 during cropping were much higher than would be expected assuming that nitrogen was only lost in the crop, the rejected stumps and soil mycelium. Assuming a total nitrogen of 0·8% in fresh mushrooms (about 8% of the dry matter) Table 51 compares the actual loss of nitrogen with that removed in the mushrooms.

Table 51

Experiment	Mean Yield lb./sq. ft.	Nitrogen removed in mushrooms lb./sq. ft.	Nitrogen lost lb./sq. ft.
1	1·7	·014	·059
3	1·0	·008	·026
5	1·3	·012	·041

Mushroom stumps and mycelium removed during cropping represent about 20% of the crop, but they have a lower nitrogen content than mushrooms (2·3% of the dry matter). Preliminary analyses also show that a small increase in nitrogen occurs in the casing soil but neither of these effects is enough to account for the discrepancy.

In Experiment 5 the nitrogen loss bore a highly significant relation to the percentage of original nitrogen and the corresponding figures for Experiments 1 and 3 supported this relation with the exception of two



pairs (Diagram 10). The fact that percentages were correlated and not actual lb./sq. ft. indicates that the losses of nitrogen were not connected with the mushroom cropping but with some process taking place throughout the compost. It seems probable that denitrification takes place, in

a manner analogous to denitrification during composting. In each case the rate is dependent upon the percentage nitrogen present. In the case of the cropping period it is likely that the final product is gaseous nitrogen and not ammonia since no odour of ammonia is perceptible, whereas quite a small evolution of ammonia would be detected in a closed mushroom house.

Other Changes

Calcium, magnesium, phosphorus and potash changes are being investigated but a sufficient number of results have not yet been obtained to justify any discussion.

Physical Properties of Compost

Probably the dominating physical requirement of a compost is that it should be as aerobic as possible, but there is also the opposing requirement that it should be as dense as possible in order to obtain good water holding and retaining properties and to ensure as high a concentration of nutrients as possible. A first-class horse manure compost appears to obtain the optimum balance between the two opposing requirements whereas in general, synthetic composts are highly aerobic but lack density. Apart from extraneous factors such as temperature, air currents, the type of casing soil and shelving used, the aeration of compost depends on the size and distribution of air spaces in the compost. These are affected by four main factors :—

1. The size distribution of the solid matter. A good grading of sizes will produce a dense compost, but Pizer (1937) found that if dispersed colloids are also present the finer pores are blocked and an anaerobic compost results. It is possible that the more highly aerobic synthetic composts may contain a higher proportion of dispersed colloids than denser composts without detrimental effect.
2. Pressure exerted when filling the beds.
3. Toughness of the straw. A tough straw will resist pressure during filling, so retaining air spaces, and will tend to give a lighter compost, although extra pressure during filling may partially overcome this.
4. Moisture content. Excess moisture fills the fine pores and tends to give an anaerobic compost.

As stated previously empirical methods are being worked out for the measurement of density and size distribution (including dispersed colloids). So far these measurements have shown that :—

1. The higher levels of nitrogen tended to give denser composts.
2. Phosphate levels had no discernible effect on density.
3. Blood meal composts were richer in the colloidal fraction than were inorganic nitrogen composts.
4. Gypsum did not always produce a high enough calcium ion concentration to flocculate all the colloids. Superphosphate corrected the deficiency. This lack is probably not of any importance and in any case addition of excess of superphosphate is probably detrimental in other ways.

5. Synthetic composts using about 3 cwt. dried blood per ton of straw as source of nitrogen and not containing soil had a density of about 7 lb. dry matter per cu. ft., i.e., they provided about 4 lb. dry matter per sq. ft. of bed area at a depth of 7″. Heavy horse manure composts generally provide about 7 to 10 lb. dry matter per sq. ft.

Pizer's (1937) findings on the beneficial effect of adding gypsum to horse manure compost in order to flocculate the colloids emphasise the importance of the colloidal fraction and for this reason some work has been done on this subject. It was found that trivalent cations such as iron and aluminium are more effective than mono and divalent ions in flocculating compost colloids. A horse manure compost, not treated with gypsum, was moistened with water and the liquid pressed out and treated with various concentrations of salts and allowed to settle in separate test tubes. The sediment heights, assumed to be an indication of the extent of flocculation, are set out in Table 52.

Table 52—Sediment Height in mm.
(No added salts—9 mm.)

Molar Strength	LiCl	Na_2SO_4	$MgSO_4$	$CaCl_2$	$Al_2(SO_4)_3$	$Fe_2(SO_4)_3$
0·0025					27	25
0·005					42	49
0·01				16	93	95
0·025			23	28		
0·1	10	12	30	71		
0·5	34	36				
1·0		37	30			
2·0	35					

Gypsum provides calcium ions in solution of less than 0·02 M strength so that in this case at least it would not be a very effective flocculant compared with iron or aluminium salts. It is thus possible that in some cases a small concentration of trivalent cations may improve mycelial growth, but no conclusive evidence has yet been obtained that this is so.

Table 53—Analysis of Materials of Possible Use in Composting

	Moisture	Total Ash	Acid Insoluble Ash	Total N	Protein N	P	K	Ca	Mg
	% Fresh Sample	% Dry Matter							
Wheat Straw	15·4	6·7	5·8	0·35	0·27	0·08	1·25	0·27	trace
Ditto after wetting	69·4	8·1	5·8	0·36	0·28	0·14	0·61	0·36	trace
Scrap Leather : Sole[1]	22·7	4·7	—	6·37	6·33	—	—	—	—
,, ,, Upper, Veg. tanned[1]	20·0	5·3	—	8·38	7·08	—	—	—	—
,, ,, Chrome tanned[1]	23·4	6·9	—	13·50	13·5	—	—	—	—
Leather Dust[1]	17·1	5·2	—	6·09	6·17	—	—	—	—
Leather Shavings[2]	41·5	2·3	—	7·34	7·3	—	0·25	—	—
Dried Sewage Sludge	7·7	—	—	1·60	—	—	—	—	—
Castor Bean Meal	12·3	—	—	5·20	—	—	—	—	—
Fresh Male Fern (September)	71·5	—	—	1·51	—	—	—	—	—
Beet Tailings[3]	82·4	73·6	40·8	5·79	—	0·07	—	8·7	—
Dried Blood[4]	9·5	2·92	0·33	13·87	13·80	0·28	—	0·09	—
Cocoa Bean Waste[5]	50·5	46·1	—	2·45	—	—	—	12·93	0·20
Dried Rabbit Fur Waste[5]	7·62	—	—	11·55	—	0·16	—	—	—
Dried Organic Residue[5]	7·60	48·3	—	—	—	—	—	—	—
Limed Animal Manure[5]	44·6	26·94	—	0·74	—	0·03	—	4·24	—
Weathered Wheat Straw (Baled) A	—	—	—	—	—	0·08	1·06	—	—
Weathered Wheat Straw (Baled) B	—	—	—	—	—	0·06	1·22	—	—
Hide Meal[6]	11·1	—	—	7·70	—	nil	—	—	—
Manurite[7]	45·3	—	—	2·65	—	1·40	—	—	—

Suppliers :—

1. J. Masters
2. Wibberley & Felstead.
3. British Sugar Corporation, Peterborough
4. Thomas Elliott
5. Couper, Friend & Co.
6. Vitax Fertilisers Ltd., Ormskirk
7. C.A.E.C. Howard Ltd., Birmingham

Wetting Agents

The use of wetting agents for wetting straw for synthetic composts has been suggested and the efficiency of various wetting agents has therefore been tested by the sinking method, using small pieces of straw floating on water containing various detergents. The cationic detergent Fixanol C was not very efficient and non-ionic ones (e.g., Lissapol N) were probably more effective than anionic ones (e.g., Calsolene HS and D10) although both were good. Neither anionic nor non-ionic wetting agents had any effect on the flocculation of compost colloids by cations. High concentrations of cationic wetting agents tended to flocculate compost in a similar manner to inorganic cations.

Composting Materials

Partial analyses have been done on a number of waste materials of possible use in composting and the results are given in Table 53.

Aerobic Medium for Growth Experiments

An aerobic medium for pure culture experiments with mushroom mycelium, based on milled cellulose clippings, has been prepared and used in some preliminary experiments (Burrows, 1949).

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MICROBIOLOGY DEPARTMENT

C. J. La Touche

The work in this department may be conveniently described under five headings :—

1. Technique.
2. The composting process.
3. Mushroom growth.
4. Microbiology of mushroom beds.
5. Diseases and competitors of the mushroom.

Technique

In examining composts, casing soil, and mushroom beds, it was desirable to be able to distinguish actively-growing fungi from those present only in resting forms. A new form of slide-trap was used for collecting moulds from these media and has already been described (La Touche, 1948). This simple device collects growing mycelium uncontaminated by spores. As the investigations progressed improvements in this technique developed, especially as regards the slides and media used ; thus, in the case of the slides, those with three cavities increased the number of moulds obtained, while as regards media, a soil extract medium with addition of Rose Bengal (0·0067%) Brian (1947), reduced the growth of bacteria due to contamination during transfer operations from slide-trap to Petri-dish. Moulds belonging to about ten different genera were obtained from casing-soils by this method but did not include species of *Penicillium, Mucor* nor *Cladosporium.*

The following genera were represented in a comparison of three methods applied to the casing-soil on a single mushroom bed :—

1. Slide-trap method : *Gliocladium, Fusarium, Cylindrocarpon.*
2. Dilution method : *Verticillium, Trichoderma, Mortierella, Mucor, Penicillium.*
3. Direct sowing of soil particles on agar : *Mucor, Mortierella, Verticillium.*

From these and other data collected from time to time it seems that as regards the casing soil used for the experiments, populations obtained by the slide-trap method show a preponderance of species of *Fusarium* and *Cylindrocarpon :* populations obtained by the dilution method show a greater variety than the other two methods, but if platings from a high dilution (approx. 1 : 1,000) are compared with those from a low dilution (approx. 1 : 100) it is found that *Penicillium* spp. are relatively abundant at the high dilution whereas at the low dilution they are absent, and that, on the other hand, *Mucor* spp. are present at the low dilution whereas they are absent at the high dilution. This indicates perhaps an inhibiting action by *Mucor* spp. on the development of *Penicillium* spp. Support for this possible explanation was provided by the results of using the particle method which showed a preponderance of *Mucor* spp. and *Mortierella* spp.

In another set of experiments, traps buried in the same casing-soil, but obtained directly from the soil store-shed, again yielded a preponderance of *Fusarium* and *Cylindrocarpon* spp. but included also *Gliocladium* sp., *Alternaria* sp. and some other unidentified moulds,

while direct plantings of this soil on agar yielded *Mucor* sp., *Mortierella* sp. and *Absidia* sp. as well as *Alternaria* sp. and *Trichoderma* sp. *Mucor* spp. have never at any time been obtained in the slide-traps, but *Mortierella* spp. have been obtained in them occasionally. Likewise, *Penicillium* spp. have consistently been absent from slide-trap collections.

Experiments in which slide-traps were suspended in beakers on the sides of which were growing pure cultures of moulds belonging to the genera *Absidia*, *Penicillium* and *Cladosporium* which had not been obtained in traps from the soil, showed that under these conditions *Absidia* sp. entered readily, *Cladosporium* sp. after a long interval and *Penicillium* sp. not at all.

Work on these lines was not sufficiently extensive to permit of definite conclusions regarding which moulds are active in casing-soils and composts of mushroom beds and which are not. The fact that the mycelium of the cultivated mushroom does not enter the slide-trap is a point in favour of using this method for investigations of microfungi in mushroom beds, but it also implies that the method may be too selective, and therefore not provide a representative picture of the active microfungi. The beaker experiments with *Penicillium* sp. also suggest this.

Trials with contact-slides, slide-traps, and sheets of transparent cellulose film (a method devised by Dr. G. C. Dobbs, of Bangor) in fermenting wheat-straw in beakers at 45° C. showed that, for direct microscopic examination the cellulose film was the most satisfactory for collecting moulds under these conditions. Slide-traps were not satisfactory for this purpose as the fast-growing moulds such as *Mucor pusillus* and *Aspergillus fumigatus* tended to become established abundantly within a very short time, and also the moisture which seeped in between the slides introduced bacteria and protozoa in large numbers and rendered impractical the identification of such moulds as had entered. The best method of isolating the moulds for pure culture was that of picking off fruiting structures, such as conidiophores, sporangiophores and perithecia with a sterile needle, while using a hand-lens, and then proceeding, by various purification techniques, to obtain them in pure culture. A small number of moulds capable of growing at an elevated temperature (45° C. and higher temperatures in some cases), was isolated in this manner from wet straw alone. This number includes several new species, which have been or are being described separately. The fact that these moulds can be grown on wet straw alone shows that highly nutritive materials such as horse manure and synthetic manures with a high nitrogen content are not essential for their growth. It is also probable that they are widely distributed in nature on a variety of materials in the form of spores or resting mycelium, but require a high temperature and high relative humidity to enable them to grow.

Composting

Composted horse manure has long been the recognised medium for mushroom cultivation and has usually given results better than other forms of compost, so that its superiority has been generally accepted.

It was considered by us that this superiority might be due, amongst other factors, to a characteristic flora not occurring in other fermenting materials. An investigation was therefore started to identify fungi present in this type of compost and in the synthetic type. This could not be made quantitative, nor could a specific name be given to every fungus since in fact some of these have not been described elsewhere, but the following lists give the specific names of some and the generic names of others for fungi found in horse manure, synthetic compost based on straw with dried blood, and wet straw incubated at 45° C. (113° F.).

Horse Manure

Aspergillus fumigatus
Thermomyces lanuginosus
Coprinus sp.
Actinomyces sp.
M.R.A. 32
Mucor Pusillus Lindt.

Straw and Dried Blood Synthetic Composts

Aspergillus fumigatus
Thermomyces lanuginosus
Mucor pusillus
Actinomyces sp.
Chaetomium thermophile n.sp.
Chaetomium sp. M.R.A. 272
Monotospora sp. M.R.A. 75
M.R.A. 32

Wet Straw

Aspergillus fumigatus
Thermomyces lanuginosus
Mucor Pusillus Lindt.
Actinomyces sp.
Chaetomium thermophile n.sp.
Chaetomium M.R.A. 272
Monotospora sp. (*like M.R.A.* 75)
Micromonospora sp.
M.R.A. 32

It was observed that M.R.A. 32 developed early in the composting process and that *Thermomyces lanuginosus* was predominant in the later stages.

In stacks, *Actinomyces sp.* as well as Gram positive rod-shaped bacteria were present at the highest temperatures and *Coprinus sp.* near the surface of the stack especially on composts rich in nitrogen.

The following list shows the effect of temperature on the moulds, bacteria, etc., growing on straw in a saturated atmosphere:

45° C.

Mucor pusillus Lindt. (M.R.A. 233)	++++
Aspergillus fumigatus (M.R.A. 221)	++++++
Monotospora sp. (like M.R.A. 75)	+++
Chaetomium thermophile n.sp. (like M.R.A. 112)	++
Mould resembling M.R.A. 32, unidentified	++++
Micromonospora sp. (not in culture)	+++
Thermomyces lanuginosus Tsilinsky (like M.R.A .140)	++++
Bacteria and Protozoa	

50° C.

Mucor pusillus Lindt.	++
Aspergillus fumigatus	++
Monotospora sp.	++
Chaetomium thermophile n.sp.	++
Thermomyces lanuginosus	++++

Bacteria

55°C.

Thermomyces lanuginosus	+++

Bacteria : various

60° C.

Gram+bacteria (rods).

The following hitherto undescribed fungi were isolated from straw during fermentation with or without the addition of other materials:

M.R.A. No. 32

This fungus occurs frequently on composting horse manure on the surface or slightly below it, forming quite extensive patches, sometimes up to several feet in diameter, of white floccose mycelium which becomes powdered a cream colour when producing spores. Its growth is most luxuriant when the composting stack is producing clouds of steam. It can be isolated on the spot to culture media and purified later if necessary. It can be obtained in the laboratory by incubating various types of synthetic manure at temperatures between 40° C. and 50° C., or simply by incubating some straw with a little water at these temperatures. It usually appears early in the process of fermentation and soon becomes overgrown by other thermophile fungi.

M.R.A. No. 75

This fungus which is a species of *Monotospora* was readily isolated from composting horse manure or from various synthetic composts with a straw base, or even from straw fermenting by itself. Between 40° C. and 50° C. it grows profusely on these materials, forming at first a sparse growth composed of fine colourless or greyish mycelium which becomes gradually powdered black with spores. It is usually accompanied by other thermophile fungi such as *Aspergillus fumigatus*, *Mucor pusillus* Lindt. and *Thermomyces lanuginosus*, to mention only the more conspicuous of its fungal associates.

M.R.A. No. 272

This is a species of *Chaetomium* which was first isolated in the Sugar Beet Factory at Peterborough, from some straw which was used for packing round a carboy. The straw, after four days' incubation with a little water in a beaker at 45° C., showed numerous perithecia scattered over its surface. This fungus was found subsequently quite frequently with other thermophile fungi on the straw of synthetic composts which were incubated in the laboratory. Superficially, it is distinguishable quite readily, when grown in pure culture on straw, from *Chaetomium thermophile*, La Touche (1949), by the more discrete distribution of its perithecia on the surface of the straw and by their colour when mature, which is greenish grey instead of brown.

These three fungi will be described in detail elsewhere.

Examination of Mushroom Mycelium

A microchemical examination of mycelium (strands and individual hyphae) was undertaken in a compost contained in a box. The mycelium was examined at different levels from below upwards after staining with iodine. The larger hyphae in the strands were not coated with Ca oxalate crystals whereas the smaller hyphae were. The larger hyphae in the strands at all levels contained abundant glycogen. This seems to indicate that the larger hyphae contain the reserves and that the smaller ones absorb and synthesize the food which is transferred in part to the larger.

Effect of Growth Substances on Mushroom Growth in Vitro.

When malt extract was added to a synthetic basal medium measurements of diameters of mushroom mycelium in culture showed a beneficial effect due to the addition of 0·1%. Using soil extract medium with the same additions of malt extract the results were assayed by means of diameters and also by densities estimated with the Spekker Absorptiometer. The results of these experiments showed that the diameter of the colonies and density of growth of mycelium both respond to the addition of malt extract. The responses were rather variable and were not completely satisfactory as a basis for quantitative work, such as the determination of optimal concentrations of nutrients, but could be used in qualitative work to determine which nutrients are essential. The diameter and density are not always related, and may be differently affected by changes in the basal medium.

Growth of Mushroom Mycelium on Agar Medium Containing Leather Waste

Different types of leather waste were added to malt agar and sterilized. Mycelium was produced only in the case of the controls and in the case of the malt agar plus chrome leather. It grew well on this medium.

Effect of Cladosporium on Growth of Mushroom Mycelium

A species of *Cladosporium* which occurred as a contaminant on a culture of mushroom mycelium was over-run by the latter sooner than the surrounding medium. It was concluded that this mould probably possessed some property which was benificial to the mushroom mycelium. The interesting discovery was made some years ago that this and some other moulds synthesize lignin-like substances.

Moulds Causing Disease in Mushrooms

The majority of the moulds causing disease in mushroom fruit bodies were maintained in culture and some of these were studied closely, particularly *Verticillium psalliotae* and *Dactylium dendroides*. Notes regarding spore production in the former were published (La Touche, 1947, 1949). Certain moulds, e.g., *Trichoderma viride* and a *Penicillium* with mauve coloured spores were found associated with diseased mushrooms and must be considered as suspect.

When plates of malt extract agar and soil extract agar were exposed to the air in a mushroom house during cropping, the moulds isolated

included large numbers of *Penicillium*, some *Cladosporium*, *Aspergillus*, *Alternaria*, *Macrosporium*, and *Verticillium psalliotae*. *V. psalliotae* was also isolated from the casing soil of this house, and the fact that no diseased mushrooms were found suggests that it does not attack them under the prevailing conditions, i.e., temperature below 15° C. (59° F.) and relative humidity usually about 80% never above 90%. This view was supported by the isolation of *V. psalliotae* from the air of a cropping house on another occasion under similar conditions of temperature and humidity, no mushrooms being attacked (see also Treschow, 1941).

In the course of observations on the degree of contamination of the atmosphere in the experimental mushroom house it was noticed that *Verticillium psalliotae* had a marked antibiotic effect on a *Cladosporium sp.* which was also a contaminant. This observation was followed up by testing *V. psalliotae* in culture for antibiotic effect against all the mushroom disease-producing fungi so far collected and also against *Pseudomonas tolaasii*, the cause of "Bacterial blotch." Definite antibiotic activity was observed *in vitro* against one mushroom pathogen, namely, *Mycogone perniciosa*, and one mushroom bed invader, namely, *Papulaspora byssina* (Brown Plaster Mould). The antibiotic filtrate appears to be harmless to mushroom mycelium. This work was not continued owing to lack of time.

Fungi Identified on Mushroom or Mushroom Beds

The following fungi have been identified during the period under review on M.R.A. beds and in material received from growers:

Parasitic on Mushrooms	Invaders of Mushroom Beds established as harmful
Verticillium psalliotae	*Papulaspora byssina*
Verticillium malthousei	*Scopulariopsis fimicola*
Mycogone perniciosa	*Pseudobalsamia microspora*
Dactylium dendroides	*Myceliophthora lutea*

Fungi of Varying or Doubtful Status Identified in the Compost and/or Soil of Mushroom Beds

"Red Geotrichum"	*Trichoderma viride*
Chaetomium sp.	*Gliocladium spp.*
Geotrichum candidum	*Cunninghamella sp.*
Cylindrocarpon sp.	*Mortierella sp.*
Fusarium spp.	*Monotospora sp.*
Coprinus sp.	*Botryotrichum sp.*
**Arthrobotrys superba* or *A. cladodes var. macroides* Dreschler	*Clitopilus cretatus*
	Panaeolus campanulatus
Alternaria sp.	*Xylaria vaporaria*
Cladosporium sp.	*Panaeolus sub-balteatus*
Aspergillus sp.	*Pellicularia sp.*
Trichothecium sp.	*Harpographium sp.*
Oedocephalum fimetarium	

Fungi identified in specimens of soil intended for casing.

Fusarium spp.
Trichoderma viride
Gliocladium sp.
Sporotrichum sp.
Gliomastrix sp.
Macrosporium sp.
Botrytis cinerea
Penicillium spp.
Scopulariopsis sp.
Mucor spp.
Dematium pullulans
Dactylium dendroides
Cladosporium sp.
Cylindrocarpon sp.
Phymatotrichum sp.
Rhizopus sp.
Phoma sp.

*This fungus was found in January, 1948, at a mushroom farm near Northampton, in an area of casing soil and compost which was heavily infested with eelworms. Samples of the casing soil and compost when examined microscopically revealed compound annular traps in some of which eelworms had been caught. The fungus was identified provisionally as a species of *Arthrobotrys* and was isolated in pure culture. It has since been identified as *A. superba* or *cladodes* by Dr. Duddington, of the Regent Street Polytechnic, London.

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